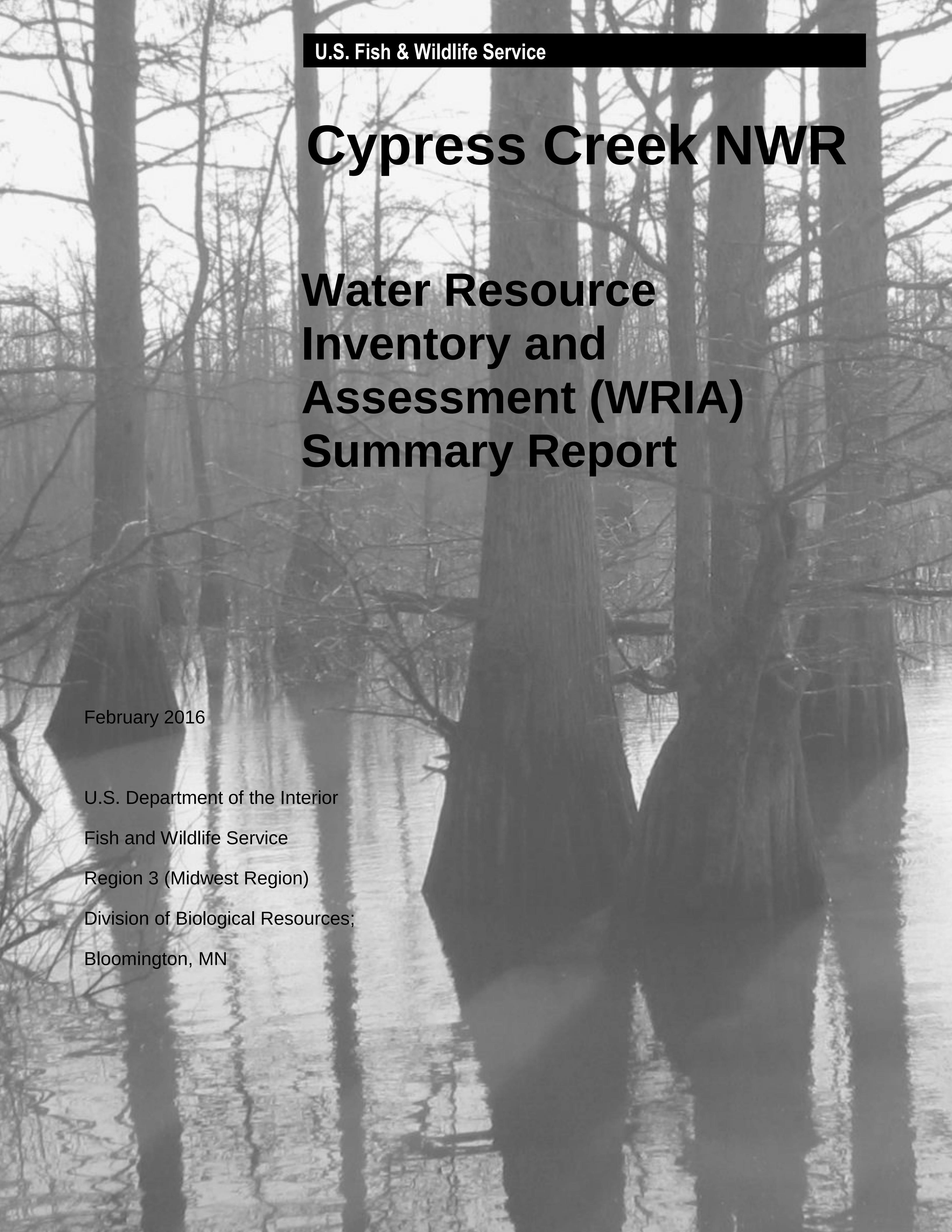

U.S. Fish & Wildlife Service

Cypress Creek NWR

Water Resource Inventory and Assessment (WRIA) Summary Report

February 2016

U.S. Department of the Interior

Fish and Wildlife Service

Region 3 (Midwest Region)

Division of Biological Resources;

Bloomington, MN

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management and where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

U.S. Fish and Wildlife Service
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National Wildlife Refuge System-Region 3
Division of Biological Resources

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Executive Summary

The Water Resource Inventory and Assessment (WRIA) is a reconnaissance-level effort, which provides:

- Descriptions of local soils, geology, and natural setting information
- Historic, current, and projected climate information, including hydroclimate trends
- An inventory of surface water and groundwater resource features
- An inventory of relevant infrastructure and water control structures
- Summaries of historical and current water resource monitoring, including descriptions of datasets for applicable monitoring sites
- Brief water quality assessments for relevant water resources
- A summary of state water laws
- A compilation of main findings and recommendations for the future

The WRIA provides inventories and assessments of water rights, water quantity, water quality, water management, climate, and other water resource issues for each Refuge. The long-term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on Refuge System water quantity and quality in order to acquire, manage, and protect adequate supplies of water. Achieving a greater understanding of existing information related to Refuge water resources will help identify potential threats to those resources and provide a basis for recommendations to field and Regional Office staff. Through an examination of previous patterns of temperature and precipitation, and an evaluation of forward-looking climate models, the U.S. Fish and Wildlife Service (USFWS) aims to address the effects of global climate change and the potential implications on habitat and wildlife management goals for a specific Refuge.

The WRIA effort has been recognized as an important part of the NWRS Inventory and Monitoring (I&M) and is identified as a need by the *Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change* (USFWS 2010a, b). I&M is one element of the U.S. Fish and Wildlife Service's climate change strategic plan to address the potential changes and challenges associated with conserving fish, wildlife and their habitats (USFWS 2011). Water Resource Inventory and Assessments have been developed by a national team comprised of U.S. Fish and Wildlife Service water resource professionals, environmental contaminants Biologists, and other Service employees.

The WRIA summary narrative supplements existing and scheduled planning documents, by describing current hydrologic related information and providing an assessment of water resource needs and issues of concern. The WRIA will be a useful tool for Refuge management and future assessments, such as a hydro-geomorphic analysis (HGM), and can be utilized as a planning tool for the Comprehensive Conservation Plan (CCP), Habitat Management Plan (HMP) and Inventory & Monitoring Plan (IMP). The Contaminants Assessment Process (CAP) is complete for the Refuge (Wiebler et al. 2001), and another assessment was initiated in 2011 by Mike Coffey (USFWS), however several sections have not been finalized. A comprehensive assessment of the Refuge's current and historic geomorphology, soils, hydrology, topography, physical anthropogenic features, and flora and fauna, was completed as part of the HGM in July, 2012 [(Heitmeyer and Mangan, 2012), ServCat reference 15796]. Many of the findings and recommendations within the CAP and HGM are applicable to water resources and are reiterated in the WRIA summary narrative.

This Water Resource Inventory and Assessment (WRIA) Summary Report for Cypress Creek NWR (CCNWR) describes current hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations regarding Refuge water resources. As part of the WRIA effort for CCNWR, water resources staff in the Division of Biological Resources (NWRS) conducted a site visit, interviewed Refuge staff, and received comments from Mike Brown (USFWS), Liz Jones (USFWS), and Karen Mangan (USFWS).

This Summary Report synthesizes a compilation of water resource data that will be stored in the national interactive online WRIA database (https://ecos.fws.gov/wria/). The information contained within this report and supporting documents will be entered into the national database for storage, online access, and consistency with future WRIAs. The database will facilitate the evaluation of water resources between regions and nationally. This report and the database are intended to be a reference for ongoing water resource management and strategy development. This is not meant to be an exhaustive nor a historical summary of water management activities at CCNWR.

1.1 Findings

The Cache River Basin today is profoundly different from the ecosystem it was before logging, agriculture, channelization, and diversion activities significantly altered the landscape. Many of the water infrastructure projects in the Watershed have had far-reaching impacts, and have modified the hydrology to a point where restoration back to the Cache River's pre-settlement state is impractical and likely impossible. The construction of the Post Creek Cutoff, which shortened the path of the Cache River to the Ohio River, has been especially instrumental in restructuring the region's hydrology, and essentially divided the Cache Basin into two subwatersheds. Such extreme alterations have disconnected the natural drainage network, changed the amount, duration, and timing of water flow, disturbed the natural hardwood forests in the area, and brought about significant sediment and erosion problems. As a result, The Cache River is an entirely different system than it once was, and generally behaves as a function of these alterations.

Average annual temperatures in the region have been hotter over the past decade, and the most dramatic temperature increases have been in the spring. Spring precipitation has also been higher over recent years, particularly in April, and the region has experienced the longest consecutive period of "wet" years on the annual scale, based on average precipitation. Higher average annual precipitation rates suggest that CCNWR may suffer from prolonged periods of higher than historic water levels. If recent trends are any indication of future conditions, then CCNWR will experience a warmer and wetter climate than it has in the past.

Areas and/or depths of inundation may change for wetlands of the Lower Cache River Basin depending on localized sedimentation and topographic constraints. In either case, seasonal wetlands and streams will likely become more permanent throughout the year, which could cause ecosystem shifts within the Refuge. Species dependent on cycles of high and low water levels in these seasonal waters could either shift upland, or disappear from the area if certain areas shift toward more permanent water regimes. Seasonal and spatial changes in contaminant, nutrient, and sediment loading would also change with streamflow patterns. Assuming permanently inundated depressions expand in the area around the Refuge, larger areas will also be subject to potential contamination as sediments and contaminants settle out.

Over the past decade, summer months have also been slightly warmer than average, though summer precipitation has generally been consistent with long term patterns. These conditions, if maintained, could potentially lead to an increase in evapotranspiration during summer months, especially if higher average rainfall during other parts of the year leads to increased rates of sedimentation, displacement of stored water, shallower average water depths in some areas, and higher average water temperatures. This may result in a stronger physical and ecological contrast between dry upland areas compared to low-lying, permanently or semi-permanently saturated areas that are strongly controlled by groundwater.

Fall has recently been wetter for a relatively long consecutive period, though there has not been much deviation of temperatures from the average seasonal mean. Since the averages for winter temperatures and precipitation have not changed drastically, and since the area currently does not receive a significant amount of snow, no significant changes in snowfall patterns are to be expected.

For unclear reasons, streamflow patterns over the entire area have not been responding as expected to recent precipitation trends. Perhaps infiltration across the watershed has increased to some extent, but in any case, a smaller quantity of runoff is reaching the stream channels despite general increases in average annual precipitation, and this observation requires additional investigation.

Runoff, sediment, nutrient, and contaminants that drain into the Lower Cache channel mainly originate from surrounding agricultural lands (Limekiln Slough, Cypress Creek, Big Creek, and Mill Creek drainages), backwater floods of the Mississippi River, large flood events of the Upper Cache River (through the breached Karnak Levee), and large flood events from the Ohio River (Demissie et al. 2008). If changes in the frequency or magnitude of storm events occur as predicted by some climate modeling scenarios (Hayhoe et al. 2004), the Lower Cache Basin may be especially vulnerable on a localized scale, and current water quality threats would be significantly more extreme. However, streamflow data from USGS gages in Big Creek near Wetaug, IL (USGS 5600000) and the Cache River near Forman, IL (USGS 3612000) (see Surface Water Quantity section), do not suggest significant increases in the frequency or magnitude of discharge from earlier records, and therefore such changes would not be expected for the immediate future.

There is a strong contrast in bed profiles between the Upper and Lower Cache River drainages, which influences the relationship between the two subwatersheds and the amounts of water flowing through each system. The Upper Watershed flowing from the Shawnee Hills exhibits a high slope, as do the major tributaries feeding the lower subwatershed, while the Lower Cache River, flowing through the historic Ohio River floodplain, naturally demonstrates very little change in elevation. The lower reaches of the Cache River have always functioned to some degree as a floodwater detention basin, but since the construction of the Post Creek Cutoff and other extreme modifications, the subbasin has experienced sediment infilling of wetland habitat, probable increases in channel bed elevation, and a reduced capacity to store water.

Sediment storage is a natural function of the Lower Channel because of its low-gradient, however higher erosion rates and increased sedimentation in the Watershed have caused these processes to become one of the most serious threats to the habitat and ecosystem. Bathymetric sedimentation surveys of the Lower Cache River Wetland area in 2000 revealed depositional rates of approximately 0.2-2cm/year (Allgire and Cahill, 2001), and the issue could increase in rate if hydrologic restoration measures are not implemented, considering wetter conditions are expected in the region in the future.

The current hydrologic state of Limekiln Slough is not conducive to CCNWR's habitat goals. The Slough naturally had a stronger connection with the Lower Cache channel, but a dredge tailing now separates the two water features and Limekiln Slough has a longer water regime, which has caused a decline in the number of tree species and increased sedimentation in the localized area.

CCNWR's contamination problems primarily include sedimentation, organic loading, nutrients, mercury, point sources, and pesticides. Mercury contamination has been reported since the 1990s, and 10.4 miles of the Cache River have had recent mercury impairments.

Some water quality differences between the Upper and Lower Cache Rivers have been noted by Scholl (2009). Macroinvertebrates in the Lower Cache River are generally more adapted to low flows and degraded habitat, and are lower in body size than communities sampled in the Upper Cache where the River's flow regime more closely resembles its natural state. This information suggests poor water quality in the Lower Basin. Similarly, IDNR fisheries surveys have shown moderately low average biotic integrity indices in the Upper Cache River basin and lower biotic integrity indices in the Lower Cache mainstem from 1992-2011 (Muir, 2011), and higher biotic integrities have generally been observed in upstream reaches compared to downstream reaches (Bennett et al. 2001).

1.2 Recommendations

The WRIA provides a collection of recommendations related to the primary findings from existing water quality and quantity information, as well as identified gaps in the water resource inventory. These recommendations are suggestions to help improve understanding of water resource quality, quantity, and limitations for Refuges, however alternative opportunities to act on current or future threats may exist. Each water resource concern and recommendation should be thoroughly assessed prior to the implementation of management actions, and when appropriate should be incorporated into the planning process with consideration for Refuges' overall goals and priorities.

CCNWR has several water resource threats and needs that are common to most Field Stations in the Midwest Region. The recommendations aimed at addressing these issues are applicable to CCNWR, as well as many other stations, and therefore present the opportunity to compare, learn from and collaborate with other field stations. These generalized recommendations include:

- Monitor water levels of managed impoundments in a common datum (i.e., mean sea level).
- Use available LiDAR data to evaluate how water levels relate to habitat management objectives and impact surrounding lands. Conduct more detailed surveys where necessary.
- Collect bathymetric surveys for managed and/or important water features, and use this information to determine optimal water level targets, compute overall water storage capacities and water distribution to meet habitat management goals and protect water supplies.
- Develop water level management plans based on topography / bathymetry information. Periodically assess the ability to achieve management targets based on monitoring data to refine future management plans and improve future infrastructure design.
- Evaluate the impact of sedimentation on water management and infrastructure to better-understand the dynamics between water storage, water basin depths, and flood frequencies, and to help anticipate future changes to these processes.

Recommendations specific to CCNWR are listed below, and additional restoration options and water resource management needs have been detailed in the HGM (Heitmeyer and Mangan 2012).

Since the Cache River and Big Creek have not responded to recent increases in precipitation based on the WRIA analysis, a more comprehensive assessment should be conducted to explore other metrics (e.g. minimum and maximum temperatures, median values for temperature and precipitation, or of datasets over various temporal and spatial scales), and verify if and how streams in this region are responding to climate change. This information will be important to predict hydroclimate trends in the immediate future and guide climate adaptation plans. In particular, climate-induced changes to the flood regime of the Mississippi River may be an important focus to determine how backwater flood patterns into the Lower Cache may change in the future.

Because of mercury contamination in the Cache River Basin, an assessment of exposure to important biota should be conducted to determine the degree to which contamination might threaten the ecosystem through bioaccumulation. In addition, greater fluctuation in water levels associated with climate or anthropogenic changes will likely increase the rate of mercury methylation, thereby magnifying the exposure risk to biota. Nearby Mingo NWR has conducted several such studies that could be replicated at CCNWR to assess the impacts of mercury contamination on biota.

Identify areas that are heavily-used by waterfowl and other important biota which may be at risk of significant decreases in water levels in the event of elevated evapotranspiration rates through spring and summer seasons. These areas could experience high concentrations of contaminants during low flow months and should be managed to minimize excessive exposure to CCNWR's wildlife.

Classify current inundation frequency for areas across CCNWR, and model and map expected future inundation distributions and frequencies to target areas of suitable bald cypress forest habitat, as discussed by Middleton and McKee (2005). This should be done with consideration for potential changes in evapotranspiration, precipitation, and other climate patterns. Additional assessments of Refuge infrastructure should be conducted based on these results.

Use available LiDAR data to create a high quality representation of water flows, improve NWI information using LiDAR terrain variables, and expand understanding of water quality concerns by analyzing erosion hotspots and sediment deposition areas and mapping flood zones at a fine scale. A HEC model, Soil and Water Assessment Tool (SWAT) model, or Stream Power Index (SPI) information all offer mechanisms that could help provide such information and help predict the long-term impacts of various management actions in CCNWR's contributing watershed.

Reconnaissance surveys should be completed to determine the most favorable option to reconnect Limekiln Slough with the Lower Cache River. Elevation, discharge, stage levels, soils, biotic parameters, as well as the integrity of the system and potential impacts to surrounding lands should be assessed in detail to help guide the decision making process. For example, the collection of bathymetry information and continuous water level information on both the Cache River and Limekiln Slough mouth area will be critical first steps towards assessing reconnection feasibility. Other disconnected waterways within the Basin should similarly be considered for reconnection where resources allow.

Introduction

Cypress Creek National Wildlife Refuge (CCNWR) is primarily located in Pulaski County, with some portions in Alexander, Union, and Johnson Counties of southern Illinois, and is part of the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (LCC). Its establishment along the Cache River and Cypress Creek channels occurred on June 26, 1990 by the authority of the Emergency Wetlands Resource Act of 1986 (16 U.S.C. 3901 b, 100Stat.3583, PL 99 645) to:

- *Protect, restore and manage wetlands and bottomland forest habitats in support of the North American Waterfowl Management Plan;*
- *To provide resting, nesting, feeding and wintering habitat for waterfowl and other migratory birds;*
- *To protect endangered and threatened species and their habitats;*
- *To provide for biodiversity;*
- *To protect a National Natural Landmark;*
- *And to increase public opportunities for compatible recreation and environmental education.*

The 16,000 acres of USFWS acquired land and 35,320 acres within the Refuge's acquisition boundary are situated at the intersection of four (level IV) ecoregions: the Southern Shawnee Hills, Cretaceous Hills, Northern Holocene Meander Belts, and Wabash-Ohio Bottomlands [71n, 72k, 73a, 72a; (USEPA 2013)]. This area is a hydrologically important and ecologically diverse area immediately north of the confluence of the Ohio and Mississippi Rivers.

Despite attempts in the past to drain the land for agriculture, this unique landscape still retains some of the country's most important wetland territory, and is accordingly known by some as "Illinois' bayou." On January 11, 1994, the Cache River and Cypress Creek Wetland Complex earned a Ramsar designation as a "Wetland of International Importance," in part because of its location on the Mississippi Flyway, where it serves as significant migration, fall staging, and wintering grounds for waterfowl.

Natural Setting

The natural setting section describes the resources associated with the Refuge, including the Cache River watershed, as well as the region's topography, geology, climate, and soils. These underlying, non-living components of an ecosystem provide the context for the form, function, and management of water resources.

1.3 The Cache River Watershed

General information

The Cache River Basin, located across Union, Johnson, Massac, Pulaski, and Alexander counties, is an ecologically significant drainage of 737 square miles. Because of this watershed's unique location near the intersection of two major rivers, four different physiographic regions, and two contrasting climate zones, it represents a rare hotspot for ecosystem diversity, supports about fifty endangered plant and animal species (Duram et al., 2004), and contains approximately 71.7 miles of biologically significant streams (IDNR 2001).

The Cache River has its beginnings near Cobden, Illinois in Union County, north of the Refuge in the Shawnee Hills region. Ridges of this area rise above most of the Refuge's bottomland habitat and are dominated at their base by hardwood forests containing overcup oak (*Quercus lyrata*), pin oak (*Quercus palustris*), cherrybark oak (*Quercus pagoda*), sweetgum (*Liquidambar styraciflua*) , red oak (*Quercus falcate*), white oak (Quercus alba) and shagbark hickory(*Carya ovata*) (IDNR 2014). Atop the ridges are areas of exposed bedrock and thin soils, as well as communities of post (*Quercus stellata*) and blackjack oaks (*Quercus marilandica*), open grasslands, forbs, and dry prairies. The Cache River courses through these hills into the Coastal Plains of southern Illinois, where the landscape transitions into deeper, open, and more-permanent water regimes that contain Cypress (*Taxodium distichum*) and Tupelo (*Nyssa aquatica*) tree communities and thickets of buttonbush (*Cephalantrhus occidentalis*) in shallower areas (IDNR 2014). This habitat is particularly pronounced within the Lower Cache River Swamps between Karnak, IL and Ullin, IL.

While its headwaters are surrounded by a large area of state forest and parkland, stream alterations and land use activities along the river's 110 mile journey downstream impair water quality and offset any potential protection and buffering effects these protected areas might offer. Various diversion and channelization projects, as well as mass land clearing, field tiling, and ditch construction, all contributed to the area's altered landscape, modefied flow regimes, and degraded water quality (Heitmeyer and Mangan, 2012).

Land use changes and hydrologic alterations

Much of the previously-forested and saturated areas of the Cache River Watershed have been cleared and drained for lumber and agricultural purposes since the 1800s (Heitmeyer and Mangan, 2012). Upland areas, which are particularly vulnerable to erosion, were converted to cropland first, then throughout the mid- to late- 20th century, agricultural practices in these areas declined and returned to forest cover while agricultural activities migrated down-gradient (Duram 2004).

Today, roughly half of the Cache River watershed land is farmed. Data from 2008 suggest that most of the agricultural land near the Refuge is used for corn and soybean production, and herbaceous grassland is intermixed, mostly outside of the acquisition boundary. A relatively small amount of this area is classified as developed by the National Land Cover Dataset (NLCD). Within the Refuge, fragmented bald cypress and water tupelo swampland can be found and represent the northernmost extent of this habitat in the country. Only small, patchy areas of degraded floodplain forests remain compared to pre-settlement extents, however. According to the NLDC these areas are intermixed primarily with herbaceous and woody wetlands or mixed forest (Heitmeyer and Mangan, 2012).

Though the Cache River Watershed still upholds a reputation as one of Illinois' most ecologically rich areas, it has an extensive history of direct hydrologic modifications which have held significant weight in the alteration of the region's ecosystems. Originally, the Cache River was an overflow path for extreme flood events (with a return interval of roughly 1-2 decades) of the Ohio River, as well as backwater floods from the Mississippi (Heitmeyer and Mangan 2012, Gough 2005). The River would frequently overflow its banks into a wide floodplain that supported bald cypress and tupelo hardwood regeneration. In the 1900s, however, the Cache River's natural path was shortened to the Ohio River by the construction of the Post Creek Cutoff in 1915 for improved agricultural drainage. Other river reaches and tributaries were also part of channelization and straightening projects in the watershed (Heitmeyer and Mangan 2012). These actions divided the Drainage into two sub-watersheds (Figure 1). The Upper Cache River now follows a shorter route into the Ohio River (RM 957.8) through the Post Creek Cutoff, which drains approximately 369 square miles of land. The Lower Cache empties roughly 358 square miles into the Mississippi River (RM 13.2) through the Mounds Diversion channel. Today, only 11 square miles of the Lower Cache follows the River's original course, and meets the Ohio River at RM 974.7. Mill Creek, Cypress Creek, Big Creek, Limekiln Slough, and Indian Camp Creek are the primary tributaries contributing flow to the Lower Cache River since its disconnection from the Upper Cache and Ohio Rivers.

Two levees constructed by USACE in 1952 further-divided the Lower Cache River from the Ohio River and Upper drainage. The Reevesville Levee was designed to keep Ohio River floods from the Cache basin in the eastern portion of the watershed, and the Karnak Levee along the Post Creek Cutoff was constructed to prevent floods from the Upper Cache and backwater from the Ohio River from entering the Lower Cache subwatershed. While the Lower Cache reach typically flowed in a westerly direction to meet the Mississippi River, some still flowed east to Post Creek Cutoff and ultimately to the Ohio River through the levee's two 48-inch gated culverts during large flood events (Demissie et al. 2008). This was due in part to incision, widening, and steepening of the Post Creek Cutoff channel following its construction, and it was estimated that this reverse flow effect significantly reduced discharges of the Lower Cache River (Hutchinson 1984).

Since the Karnak Levee failure in spring of 2002, this section of the Lower Cache is now more connected to, thus more at risk of extreme flooding from, the Upper Cache and Ohio Rivers. However even after this levee breach, the Lower Cache still experiences overall reduced flows from the Upper subbasin. Now, the direction of flow in the upper reaches of the Lower Cache River are difficult to predict, but are primarily controlled by water quantity present in Buttonland Swamp, downstream water elevations, and water volumes contributed by the Lower Cache River's tributaries. Buttonland Swamp, near the divide between the Upper and Lower Cache, is a particularly sensitive area, supporting an important community of bald cypress trees, and is threatened by sedimentation impacts associated with the Cache River's altered hydrological regime. The Diehl Dam, constructed in the 1980s to raise water levels of the Swamp, currently contributes to the reverse flow effects through Post Creek Cutoff. It also further deprives the Lower Cache of water since additional inundation increases water lost to evaporation, and is a key consideration in the management of this area.

The Upper Cache River Basin has also been seriously affected by the hydrological modifications in the Watershed. High water volumes now flow through the Post Creek Cutoff uncontrolled and have scoured and entrenched the channel significant distances upstream into the Upper Cache River Watershed (Cache River Watershed Resource Planning Committee 1995), threatening water levels and ecosystem functions of Heron Pond (Holmes, 1996). These processes may, to some degree, provide a source of the sediment deposited in downstream waters such as Buttonland Swamp during high flood events, during Ohio River backflood events, for example.

Comprehensive descriptions of the Cache River Basin, its natural history, and alterations can be found in Hutchinson et al. (2000), Corzine (2010), USACE (1992), and Demissie et al. (1990, 1992, 2001, 2007, 2008). For a summarization of restoration efforts within the Cache River Watershed, see Appendix A.

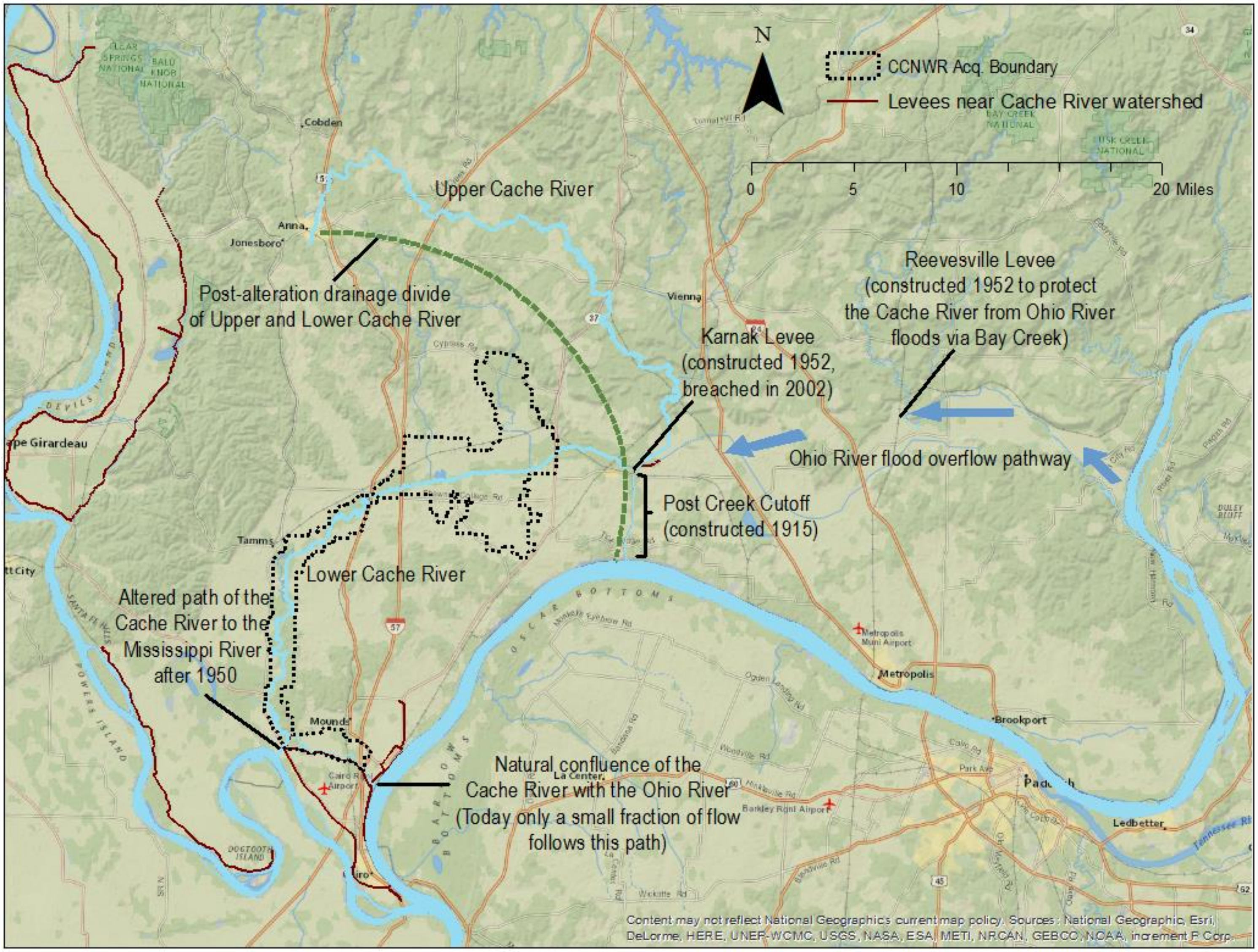


Figure 1 Major flow alterations in the Cache River Basin (adapted from IDNR 1997)

1.4 Topography

There is a strong contrast in bed profiles between the Upper and Lower Cache River drainages, which influences the relationship between the two subwatersheds and the amounts of water flowing through each system. The Upper Watershed flowing from the Shawnee Hills exhibits a high slope, as do the major tributaries feeding the lower subwatershed, while the Lower Cache River, flowing through the historic Ohio River floodplain, naturally demonstrates very little change in elevation. The lower reaches of the Cache River have always functioned to some degree as a floodwater detention basin, but since the construction of the Post Creek Cutoff and other extreme modifications, the subbasin has experienced sediment infilling of wetland habitat, probable increases in channel bed elevation, and a reduced capacity to store water.

The HGM includes a description of the Cache River Valley's (CRV) topography:

> *"Topographic relief in the CRV area that includes the acquisition boundary of Cypress Creek NWR ranges from about 280 feet above mean sea level (amsl) in the southern part of the valley to about 600 feet amsl at the top of Shawnee Hills bluffs in the northeast part of the region … The major landforms of the region include the ancient Ohio River floodplain and terraces, the steep and highly dissected Shawnee Hills to the north, and the gently rolling hills of the Coastal Plains physiographic Province to the south. Other lower gradient topography includes current and former river channels, oxbows, and relict floodplain depressions, ridge-and-swale meander scrolls on inside-bend point-bar areas of the former Ohio River and current Cache River, and remnant terraces left from eroded surrounding material during Holocene glacial outwash periods (Saucier 1994, NRCS 1999)"*

Gough (2005) discusses several surface features in the Lower Cache subwatershed. The Brownsfield terrace deposit has an elevation of approximately 5-10 feet above the modern floodplain, and sediment deposited from the Cache River's headwaters created a divide near Reevesville, IL, though this feature did not completely isolate the basin from Ohio River floodwaters after it migrated south to its current route. Other topographical features of the Cache River watershed landscape include ridges of elongated folded rock exposures, called whalebacks, and similarly-shaped depressed sloughs (Gough 2005), the largest of which is Grassy Slough near Belknap, Illinois. These forms are typically over a mile in length and were probably formed during extremely high discharge events through the Cache River valley, based on their orientation. The tops of the CRV's whalebacks typically range in elevation from approximately 340-350 feet (NGVD29).

The USGS, USACE, Illinois DOT, and the Illinois Height Modernization Program have acquired high resolution LiDAR data for Alexander, Union, Pulaski, and Johnson Counties. The datasets have been collected, processed, and merged for CCNWR's acquisition boundary and limited bordering areas (Capeder 2014).

CCNWR's digital elevation model shows that the highest elevation in the area relevant to the Refuge reaches roughly 591 feet (MSL) in the northeast, a dramatic change from the lowlands with elevations of less than 300 feet (MSL) in some areas (Figure 2).

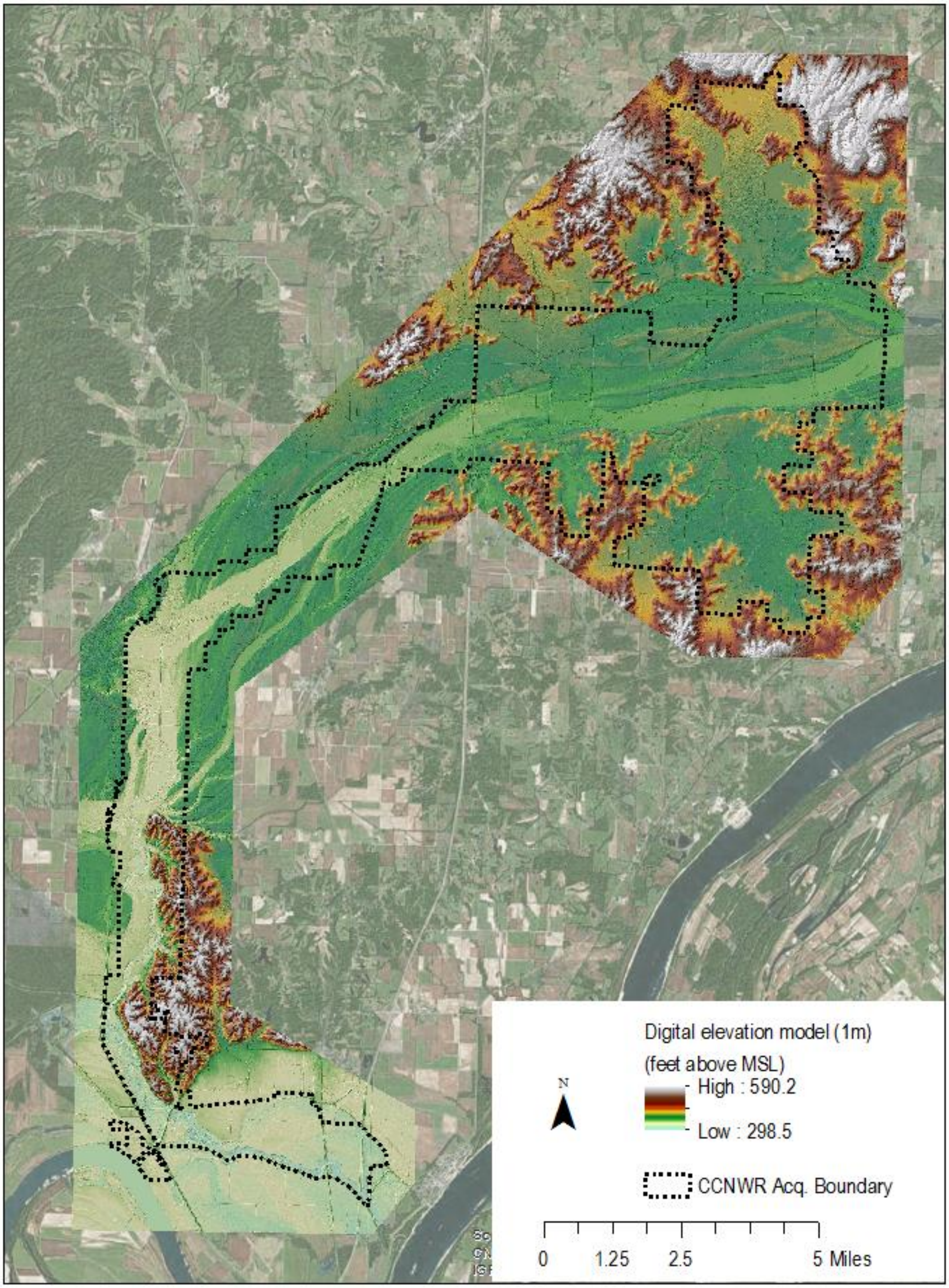


Figure 2 LiDAR elevation data (1-meter resolution) for CCNWR

1.5 Geology

Located between the Shawnee Hills in the north and the Mississippi Embayment to the south, the Lower Cache River's floodplain is roughly 3-6 miles in width (Gough 2005), and its geology was partially influenced by flows of the Tennessee River near the end of the Tertiary period (66 million to 2.58 million years ago). At that time, the River meandered through southern Illinois and carved the river valley of today's Ohio River while depositing coarse red and brown sand and gravel (Mounds Gravel), before eroding down to its modern day elevation (Heitmeyer and Mangan 2012). Then it abandoned its course, leaving behind a network of small drainages, which deposited the fine sediments that make up the Metropolis Formation underlying the Ohio River Valley and bordering terraces of the Cache River Valley today.

When the Ohio occupied the basin over 8,200 years ago, tributaries of higher gradients in the north contributed to its flow. During the Wisconsinan Glacial Episode (75,000-10,000 years ago), large amounts of sediments carried by the Ohio and Mississippi Rivers deposited and dammed these steep tributaries, forming glacial and slackwater lakes which would later become swamplands. Lacustrine deposits of slackwater clays and silts from this period formed the Equality Formation, which isfound within the Cache River's tributary valleys in thick deposits. The meltwater scoured the bedrock, causing backfilling of lake sediments which likely contributed to the Ohio River's eventual shift south (ISGS 2007). As the Ohio River channel migrated to its current course, the Cache River valley became an overflow chute for Ohio River floods that recurred approximately every 9-18 years (Heitmeyer and Mangan 2012).

The bedrock of the river valley is tilted and folded, fractured, demonstrates several faults (Figure 3, ISGS 2007), and is located in the Commerce Fault Zone, which was active as recently as 15,000 to 75,000 years ago (Gough 2005). Besides direct anthropogenic alterations in the Watershed, the area's geology, such as faulting and subsidence in response to earthquake activity in the New Madrid Seismic Zone in the early 1800s, may also have influenced the spatial hydrologic variability and formation of depressed areas in the floodplain (Gough 2005). Sunken areas in the Cache River may have also been formed by the dissolution of limestone bedrock, or by scouring from high floods (Heitmeyer and Mangan 2012).

Today, the upper basin's escarpments and narrow floodplain, which were formed during the Mesozoic Era (252 to 66 million years ago), contrast the lower subbasin's wide, flat landscape, remnant of the ancient Ohio River's historic channel. The main Cache Valley is primarily composed of, in descending order, the Cahokia Formation, the Henry Formation, the Pearl Formation, and older, unnamed sand and gravel. The Henry Formation, found in the Lower Cache subwatershed's subsurface, consists of sands, gravels, and fine outwash material. The finer Cahokia alluvium is typically 5-60 feet thick in the river valley, and has pockets of gravel in some areas.

Underlying bedrock of the Refuge is typically deepest in the northern portion and somewhat shallow in the northeast and south, with exposed bedrock near the Mississippi River north of Cairo, IL. In the north, most of the Refuge's bedrock is from the Silurian, Devonian, and Mississippian Periods of the Paleozoic Era (323-443 million years ago). Rock from the Cretaceous Era (65-144 million years ago) extends across the middle of the Refuge, while bedrock in the southern portion is dated to the Quaternary Period (from present-2 million years ago). The older geology in the north primarily consists of limestone, sandstone, siltstone, and some chert, while bedrock in the south is predominantly sandstone (Nicholson et al., 2007).

Extensive details about the Cache River Basin’s geologic history are also included in the HGM (Heitmeyer and Mangan, 2012), as well as several other publications (Demissie et al., 1990; Gough 2004).

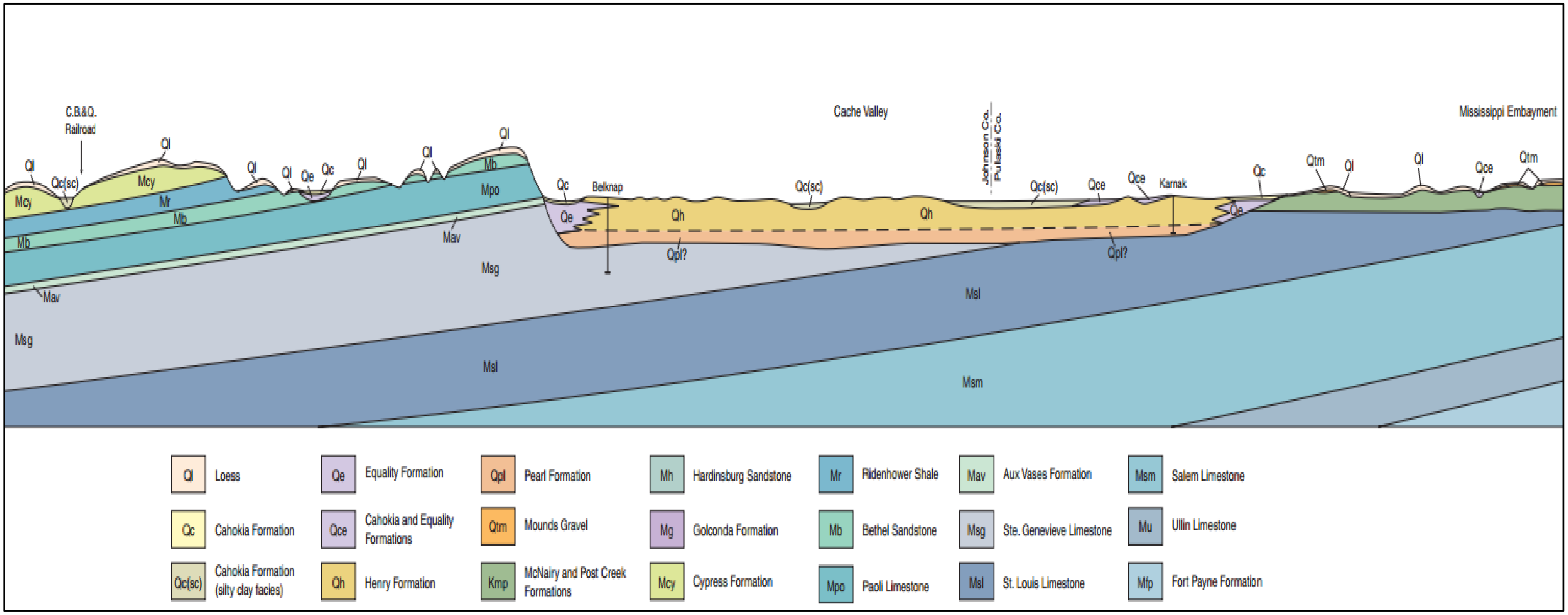


Figure 3 Cross section south of Karnak and west of the Post Creek Cutoff, illustrating the area's geology [http://crystal.isgs.uiuc.edu/maps-data-pub/isgs-quads/k/pdf-files/karnak-g.pdf; (ISGS 2007)]

1.6 Soils

Soils evolve over time because of interactions between climate, organisms, and topography, but retain some underlying physical and chemical properties based on their original parent materials. These soil-forming factors can also be confounded by human factors, and constantly work together in changing the characteristics of subsurface material. The result is a complex mosaic of soils that varies on both geographic and temporal scales. There are inherent limitations, then, with classifying, delineating, and mapping such information.

The NRCS provides detailed soils data, which is available at the county level through the Soil Survey Geography (SSURGO) Database (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Data for Alexander, Johnson, Pulaski, and Union counties are from 2013, and official soils descriptions for soil types described below (Figure 4 and Figure 5) can be found through the NRCS site (https://soilseries.sc.egov.usda.gov/osdnamequery.asp).

CCNWR is located on the southern outwash plain of the Wisconsin glacial event of 15,000 to 18,000 years ago. This alluvial deposition has given rise to varied source material. The Refuge's bottomland riverine location provided water and organic material. There are many soil types in the relatively small area of the Refuge, and the primary differences among the combinations are the coarseness of the source material. The slopes of nearly all the soils present range from 0 to 2 percent.

The Bonnie series consists of very deep, poorly drained and very poorly drained soils formed in silty alluvium on flood plains. Bonnie soils occur on nearly level flood plains and, in some places, on flood-plain steps.

The poorly drained Birds soils are on slightly higher parts of the flood plains of major streams and tributaries, but formed in alluvium that is less acid than Bonnie. They formed in silty alluvium derived from periglacial loess. This soil's native vegetation is hardwood forest.

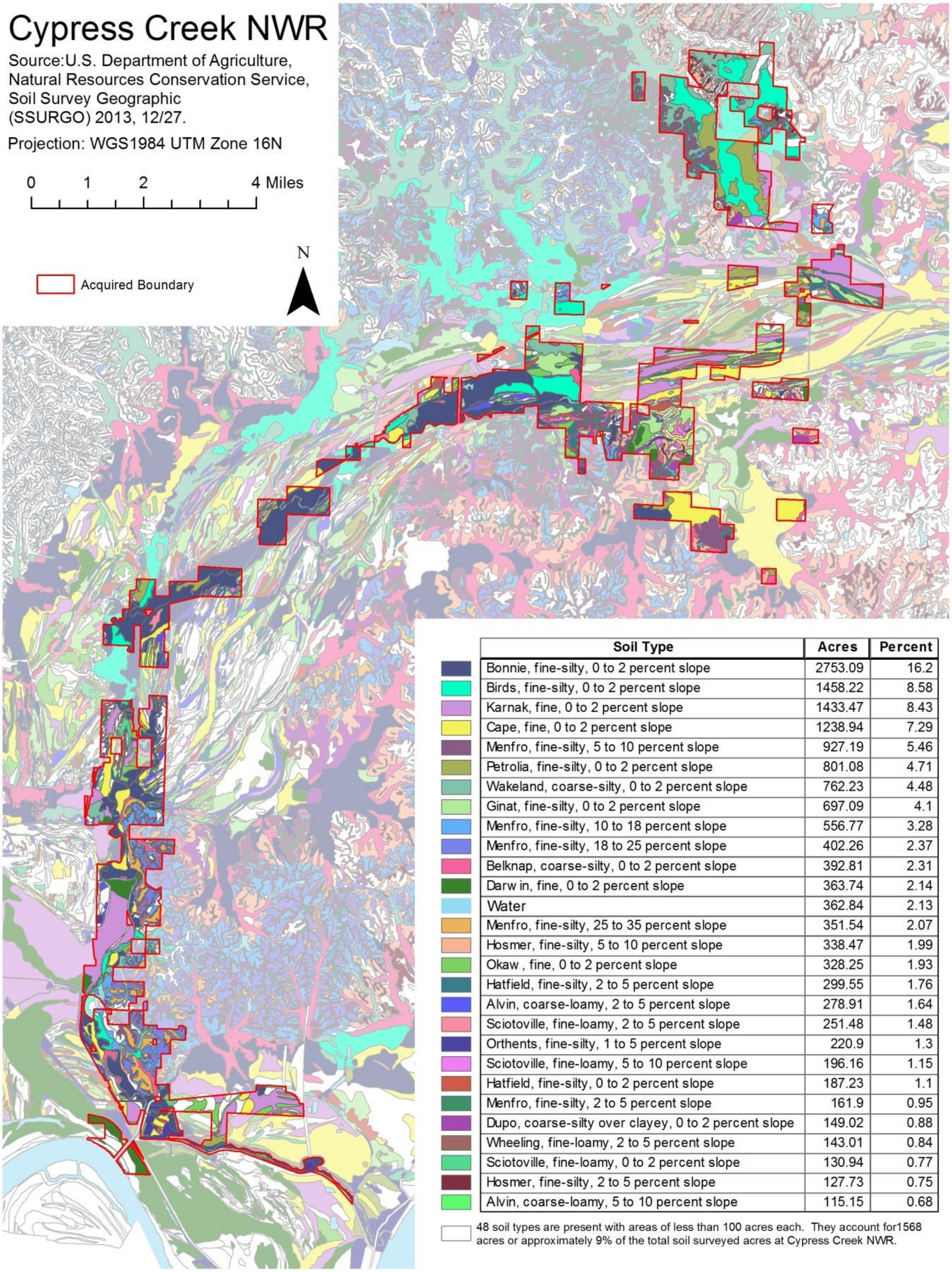
Petrolia soils are on nearly level or slightly depressional parts of flood plains or on flooded parts of glacial lake plains. Karnak soils are on low-lying parts of flood plains, principally along the Mississippi and Ohio Rivers and along their larger tributaries. Slope gradients commonly are less than one percent, but range from 0 to 2 percent. The soils formed in silty clay or clay alluvium. They have high linear extensibility and form deep, wide cracks when the soil is dry.

The Wakeland series consists of very deep, somewhat poorly drained soils that formed in silty alluvium. These soils are on flood plains and flood-plain steps.

The Ginat series consists of very deep, poorly drained soils on stream terraces. Permeability is moderate in the upper part of the solum and slow in the lower part. They formed in silty alluvium over silty, loamy and clayey slackwater alluvium. Ginat soils are on flats and in closed depressions of stream terraces along the Ohio River and its tributaries. Slopes range from 0 to 1 percent.

Darwin soils formed in fine-textured alluvium. The series consists of very deep, poorly and very poorly drained, very slowly permeable soils formed in clayey alluvium on flood plains of large streams. Darwin soils are on nearly level flood plains of large streams. Slope gradients commonly are less than 1 percent.

Occurring on the relatively higher elevations of the refuge, the Menfro series consists of very deep, well drained, moderately permeable soils formed in thick periglacial loess deposits on upland ridgetops, backslopes and benches adjacent to the Ohio River. Slopes range from 2 to 60 percent. The Menfro series' Natural vegetation is deciduous hardwoods and it is well drained.



Soil Type	Acres	Percent
Bonnie, fine-silty, 0 to 2 percent slope	2753.09	16.2
Birds, fine-silty, 0 to 2 percent slope	1458.22	8.58
Karnak, fine, 0 to 2 percent slope	1433.47	8.43
Cape, fine, 0 to 2 percent slope	1238.94	7.29
Menfro, fine-silty, 5 to 10 percent slope	927.19	5.46
Petrolia, fine-silty, 0 to 2 percent slope	801.08	4.71
Wakeland, coarse-silty, 0 to 2 percent slope	762.23	4.48
Ginat, fine-silty, 0 to 2 percent slope	697.09	4.1
Menfro, fine-silty, 10 to 18 percent slope	556.77	3.28
Menfro, fine-silty, 18 to 25 percent slope	402.26	2.37
Belknap, coarse-silty, 0 to 2 percent slope	392.81	2.31
Darw in, fine, 0 to 2 percent slope	363.74	2.14
Water	362.84	2.13
Menfro, fine-silty, 25 to 35 percent slope	351.54	2.07
Hosmer, fine-silty, 5 to 10 percent slope	338.47	1.99
Okaw , fine, 0 to 2 percent slope	328.25	1.93
Hatfield, fine-silty, 2 to 5 percent slope	299.55	1.76
Alvin, coarse-loamy, 2 to 5 percent slope	278.91	1.64
Sciotoville, fine-loamy, 2 to 5 percent slope	251.48	1.48
Orthents, fine-silty, 1 to 5 percent slope	220.9	1.3
Sciotoville, fine-loamy, 5 to 10 percent slope	196.16	1.15
Hatfield, fine-silty, 0 to 2 percent slope	187.23	1.1
Menfro, fine-silty, 2 to 5 percent slope	161.9	0.95
Dupo, coarse-silty over clayey, 0 to 2 percent slope	149.02	0.88
Wheeling, fine-loamy, 2 to 5 percent slope	143.01	0.84
Sciotoville, fine-loamy, 0 to 2 percent slope	130.94	0.77
Hosmer, fine-silty, 2 to 5 percent slope	127.73	0.75
Alvin, coarse-loamy, 5 to 10 percent slope	115.15	0.68

Figure 4 Soil types found within CCNWR's acquired boundary

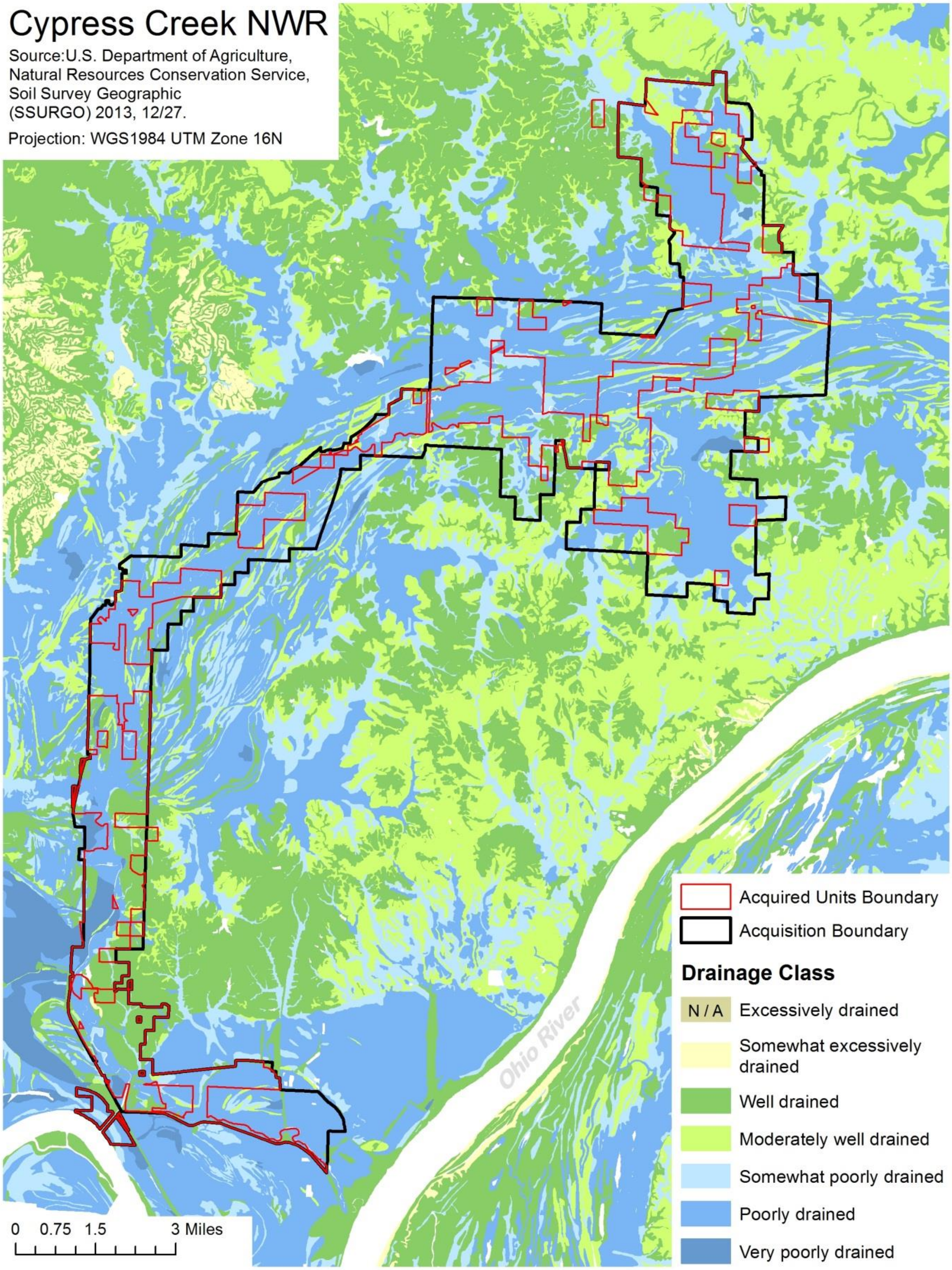


Figure 5 Soil drainage classes for soils relevant to CCNWR

1.7 Long Term Climate Trends

Climate is defined within the WRIA as the typical precipitation and temperature conditions over years or decades. Climate trends and patterns affect groundwater levels, river runoff, flooding regularity and flooding magnitude. The WRIA provides a broad overview and analysis of trends and patterns in precipitation and temperature for the region of the Refuge. This section describes CCNWR's current climate, the Hydro-Climatic Data Network (HCDN), the Parameter-elevation Relationships on Independent Slopes Model (PRISM) interpolation data relevant to CCNWR, historic changes in climate, projected climatic changes, and potential implications. There are also a number of models and studies that have evaluated current and anticipated trends in this part of the Midwest and provide supplementary information and a more comprehensive analysis (e.g. Hayhoe et al. 2010, Winkler 2012). In addition, comprehensive information about Illinois' climate, based on over 100 years of historic data, is detailed in The Illinois Climate Atlas (Changnon et al., 2004).

Current and historic conditions

The Cache River Watershed's climate is partially influenced by humid subtropical air from the Gulf, and drier continental air from the west and northwest (Duram et al., 2004). In Pulaski, Alexander, Union, and Johnson Counties, the average annual wind speed is roughly 6-7mph and strongest in the winter and spring. Wind speed is 4-5mph on average in the summer, and less than 6mph in the fall, based on data from 1991-2000 (ISWS 2009).

The climate of the Cache River Valley (CRV) area is briefly described in the HGM:

> *"The climate of the CRV is characterized by warm summers and relatively mild winters (IDNR 1997). Mean maximum/minimum temperatures in July at Anna, Illinois are 89/67° Fahrenheit (F) while similar mean maximum/minimum temperatures in January are 41/23° F … Mean annual precipitation is about 48 inches and is highest from March through May and lowest in October and January … Precipitation occurs on average about 110 days per year. Humidity is muggy from late spring through early autumn, with daytime humidity 60-80%. Thunderstorms and associated heavy showers are major sources of summer precipitation, with gusty wind, hail, and occasional tornados possible. Snow cover seldom lasts for more than a few days and constitutes only 12% of total average winter precipitation."*
>
> *"…precipitation records at Anna, IL indicate relatively regular 15-20 year patterns of greater annual precipitation in the 1920s and 1940s, late 1950s to early 1960s, the 1980s, and 2000s that alternated with lower precipitation in the 1930s, early 1950s, 1970s, and 1990s … The recurring regular patterns of alternating peak and low precipitation suggests at least some long-term regular dynamic pattern of local water inputs to the Cache River ecosystem. Long-term historic records for the Mississippi and Ohio Rivers indicate an approximate 11-15 year cycle of increasing discharge followed by declining flow and drought (Knox 1984, 1999, Franklin et al. 2003, …)"*

In addition, long-term annual precipitation datasets indicate that at least four of the wettest years in Illinois since 1895 have occurred within the past 25 years, and include 1993 (51.19 in), 2008 (50.46 in), 1990 (50.37 in), and 2009 (50.27 in) (Angel, 2010). Extreme precipitation events have historically occasionally occurred in January and February, however flooding has been most frequent in March, April, and May (Mankowski 1997). From 1971-2000 southern Illinois experienced 30-40 extreme heat days (over 95 °F) annually, and this number is expected to increase by over 20 days by 2041-2070 (Winkler et al. 2012).

PRISM and USHCN Datasets

In this section, weather data interpolated for CCNWR was evaluated and compared to data from the nearest weather station with comprehensive, high quality temperature and precipitation information. Interpolated data was obtained for the Refuge (37.277004, -89.084658) using the PRISM (Parameter-elevation Relationships on Independent Slopes Model) Data Explorer. *PRISM is an analytical tool that uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, snowfall, degree days, and dew point (http://www.wcc.nrcs.usda.gov/climate/prism.html).* The PRISM interpolation method provides spatial climate information for the conterminous United States. This grid is created with temperature and precipitation datasets and accounts for potential variation with elevation. Other orographic, topographic, and atmospheric factors are also considered in this model. The PRISM information applicable to CCNWR was used to compare data obtained from one station from the U.S. Historical Climatology Network ([USHCN]; Menne et al. 2012). The USHCN is a network of sites listed by the National Weather Service, which maintains standards in quality and continuity of data collection. This evaluation confirmed that the PRISM interpolation reflects temperature and precipitation values and trends consistent with data recorded at the USHCN site.

The closest USHCN station is located at Anna, IL (site 110187), which is roughly 20 miles north of CCNWR. Monthly precipitation data modeled by the PRISM interpolation at CCNWR (Figure 6) reflect similar values to those collected at the climate monitoring station in Anna, IL. Both exhibit the highest average monthly precipitation in May, with relatively heavy precipitation also common in March, April, November, and December. On average, the least amount of precipitation occurs in September-October. According to both datasets, average monthly precipitation ranges from about 3.2-5.4 inches.

Monthly temperatures are also similar between the PRISM (Figure 7) and USHCN sites. According to the interpolation, monthly temperatures at CCNWR range on average from approximately 33.44 °F in January to 79.08 °F in July, which are similar to the monthly averages calculated from the USHCN dataset. Average minimum, mean, and maximum temperatures for the months of October-November at the PRISM site have apparently been consistent with long-term trends (Figure 8).

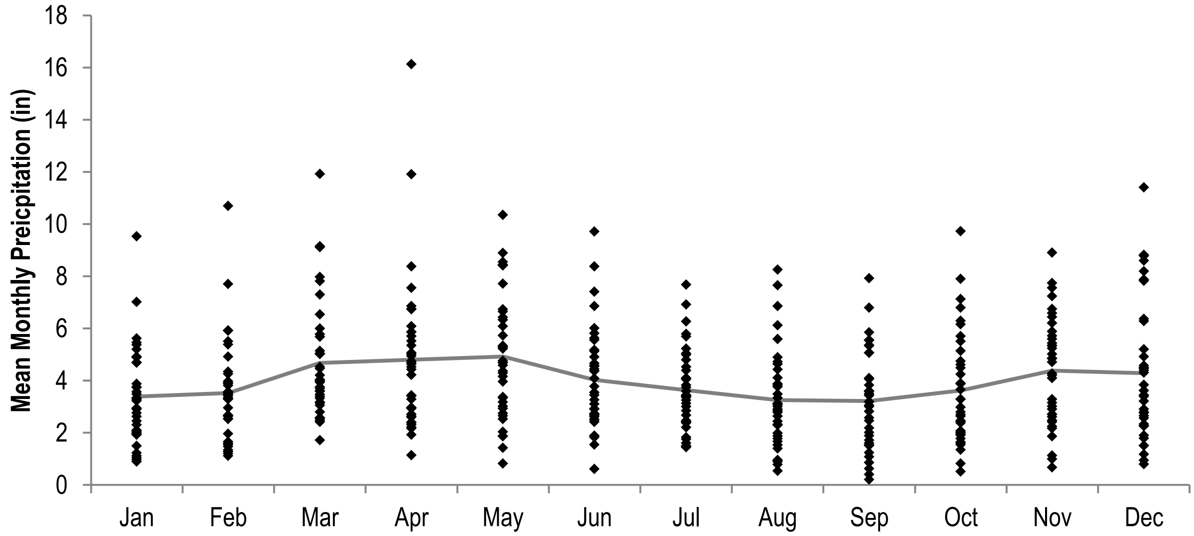


Figure 6 Average monthly precipitation data for PRISM location (http://prismmap.nacse.org/nn/index.phtml; x-coord: -89.084658 y-coord: 37.277004)

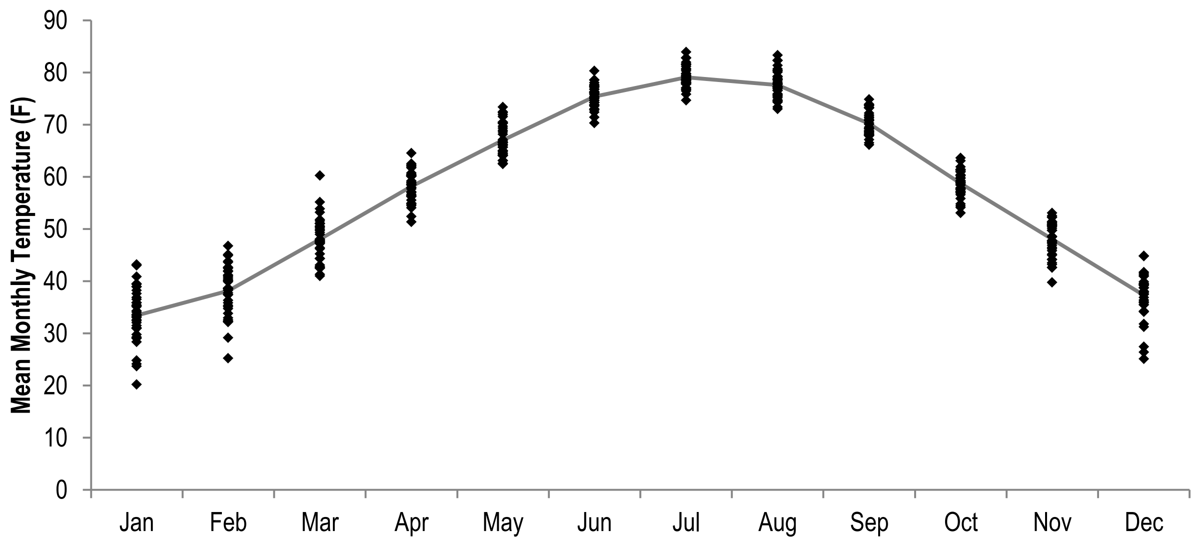


Figure 7 Monthly average mean temperatures for the PRISM location (http://prismmap.nacse.org/nn/index.phtml; x-coord: -89.084658 y-coord: 37.277004)

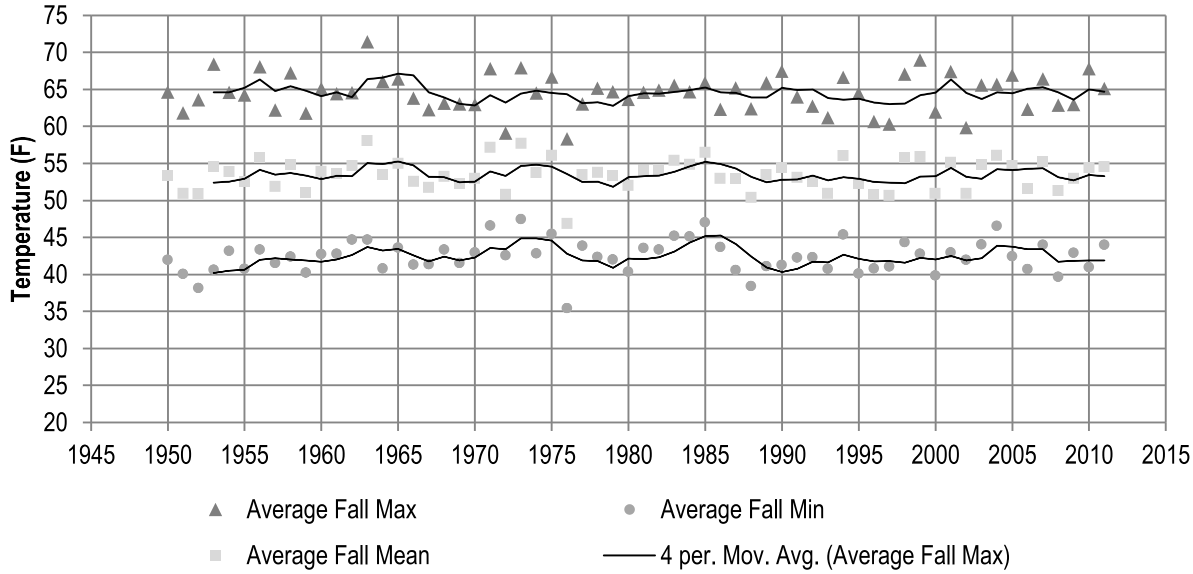


Figure 8 Autumn temperature trends (October-November) for the PRISM site (http://prismmap.nacse.org/nn/index.phtml; x-coord: -89.084658 y-coord: 37.277004)

National Climatic Data Center (NCDC) information

While the PRISM dataset has not shown any extreme trends in average, mean, or minimum temperatures for autumn compared with historical data, other seasons have shown temperature deviations from historical trends, based on generalized National Climatic Data Center (NCDC) datasets for the southwestern region of Illinois.

Annual temperature trends have shown that the general region surrounding CCNWR has experienced warmer-than-average temperatures since 1997, and a record-high average annual temperature of 59.4 degrees F was recorded in 2012 (Figure 9; SCIPP 2014). Spring has been the season with temperatures most dramatically different from past trends. This is evident by a record-long consecutive warmer-than-average period and a record-high seasonal average in 2012 of 63.2 degrees F (Figure 10; SCIPP 2014). Over the past decade, summer months have been slightly warmer than average as well. Average autumn and winter temperatures, on the other hand, have not recently shown dramatic deviations from the long-term mean. Because average winter temperatures have generally been consistent with long-term trends and the region receives a relatively small amount of snow, no significant increase in the amount of winter precipitation falling as rain rather than snow is to be expected in the immediate future.

Annual trends in precipitation data indicate the longest consecutive wetter-than-average period over the most recent years on record (Figure 11, SCIPP 2014). If these current trends are any indication of future conditions, then CCNWR will experience a warmer and wetter climate than it has in the past. Summer and winter seasons have shown recent precipitation patterns consistent with historical averages. Autumn and spring seasons have demonstrated more notable changes in precipitation. Fall has generally been wetter-than-average since the 1980s, and has recently experienced more consecutive wet years than early-record patterns (SCIPP 2014). Average spring data also shows that the two record-high seasonal precipitation averages in this region have occurred since 2008, and the 5-year moving average reached a record high in 2010. Increases in spring precipitation seem to be greatest in the month of April.

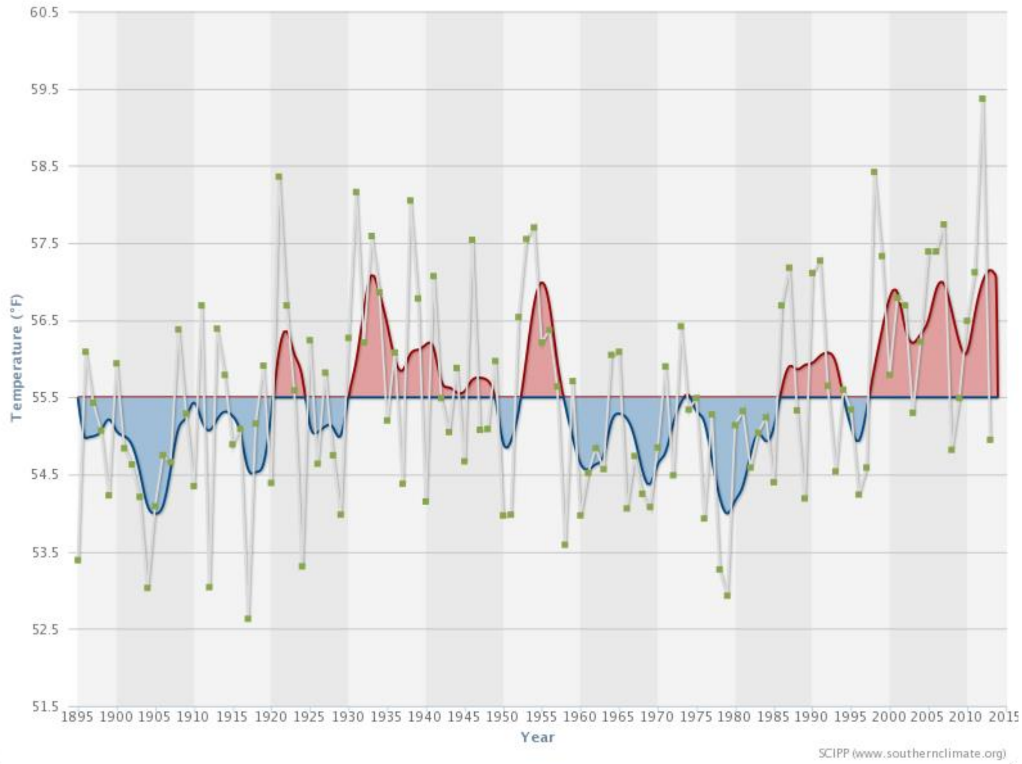


Figure 9 Average annual temperature trends for southwestern Illinois based on NCDC data (http://www.southernclimate.org/products/trends.php)

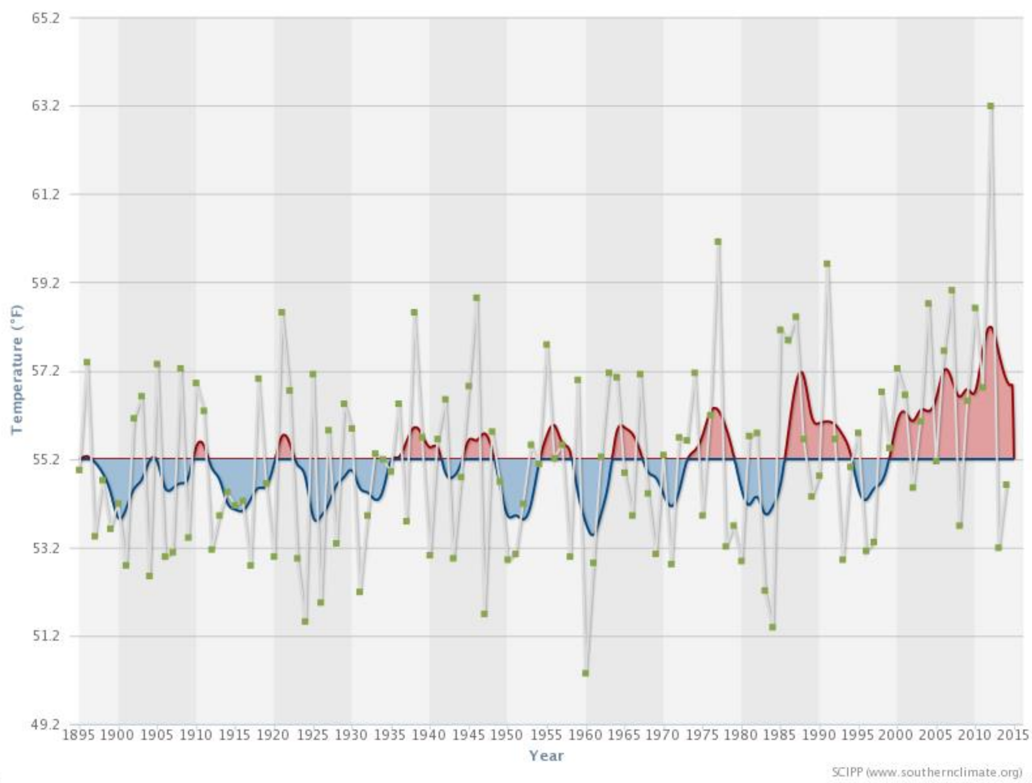


Figure 10 Average spring temperature trends for southwestern Illinois based on NCDC data (http://www.southernclimate.org/products/trends.php)

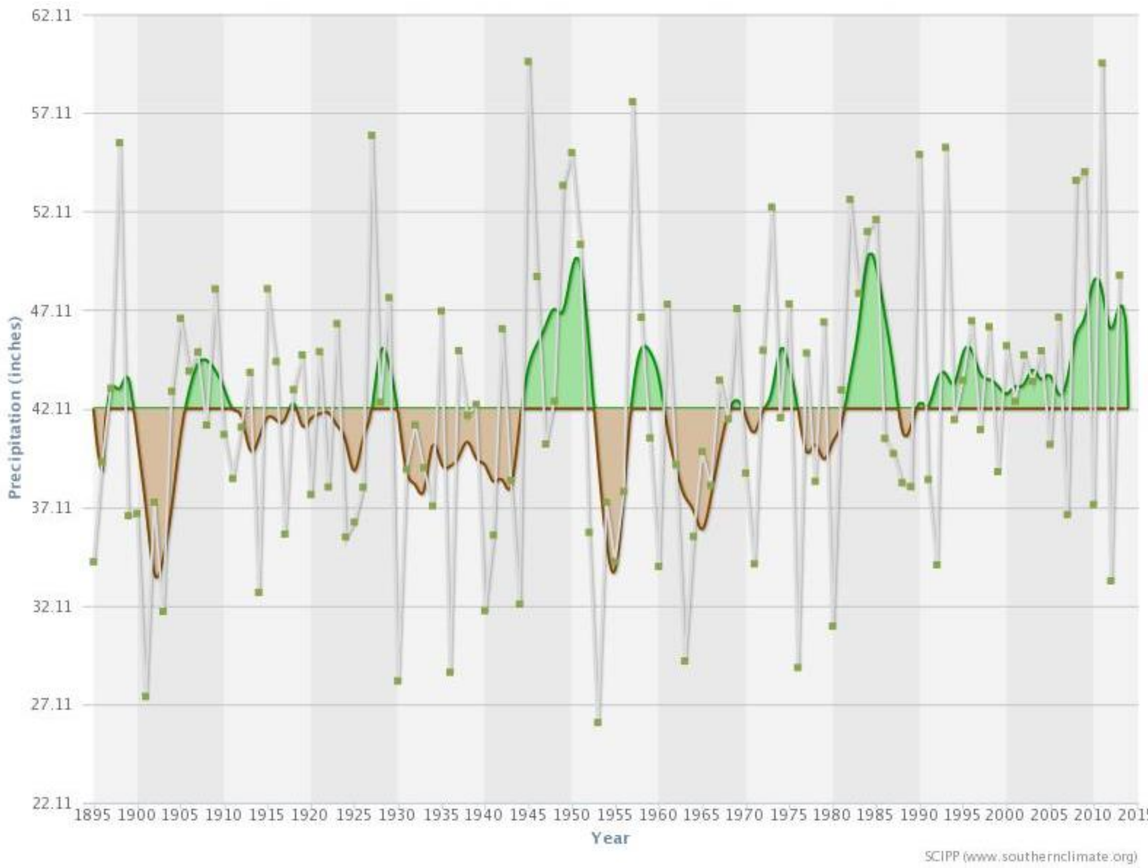


Figure 11 Average annual precipitation trends for southwestern Illinois based on NCDC data (http://www.southernclimate.org/products/trends.php)

Hydro-Climatic Data Network (HCDN)

In our assessment of the patterns in surface water quantity, we compared several of the sites qualitatively to a reference hydrograph obtained from the Hydro-Climatic Data Network (HCDN). The HCDN is a network of USGS stream gages located within relatively undisturbed watersheds, which are appropriate for evaluating trends in hydrology and climate that are affecting flow conditions (Slack et al., 1992). This network attempts to illustrate hydrologic conditions without the confounding factors of direct water manipulation and land use changes.

Located approximately two miles downstream of the Big Muddy River's confluence with the Middle Fork River, the Big Muddy River at Plumfield, IL (USGS 05597000) is the closest site that meets the criteria for the HCDN. The available data does not indicate a long-term hydro-climate change for the river at the HCDN, based on average annual and average autumn discharges (Figure 12 and Figure 13). Though slight increasing trends are apparent in both figures, neither are statistically significant. The same results were found for peak annual streamflow for the same time period.

While this gage serves as a reference and represents relatively undisturbed conditions, anthropogenic variables cannot be completely isolated. This is especially the case in this region, where the hydrology is irreversibly altered and "pristine" streams are essentially non-existent. In the case of this gage, construction of the Rend Lake Dam in 1961 altered the flow regime of the river (IEPA, 2013), and only data after dam construction and flow regulation is available for this analysis. Perhaps this is why changes that might be expected based on the climate data were not reflected at this gage, particularly for the peak annual streamflow evaluation. In addition, this gage houses a relatively small dataset beginning in the 1970s, and climate datasets were evaluated over a slightly longer period of record. It is possible that a trend would have been apparent if an earlier or more comprehensive period of record was included, or if the dam had not been constructed. A more detailed analysis of this data exploring different statistics may also expose hydro-climatic changes in this region.

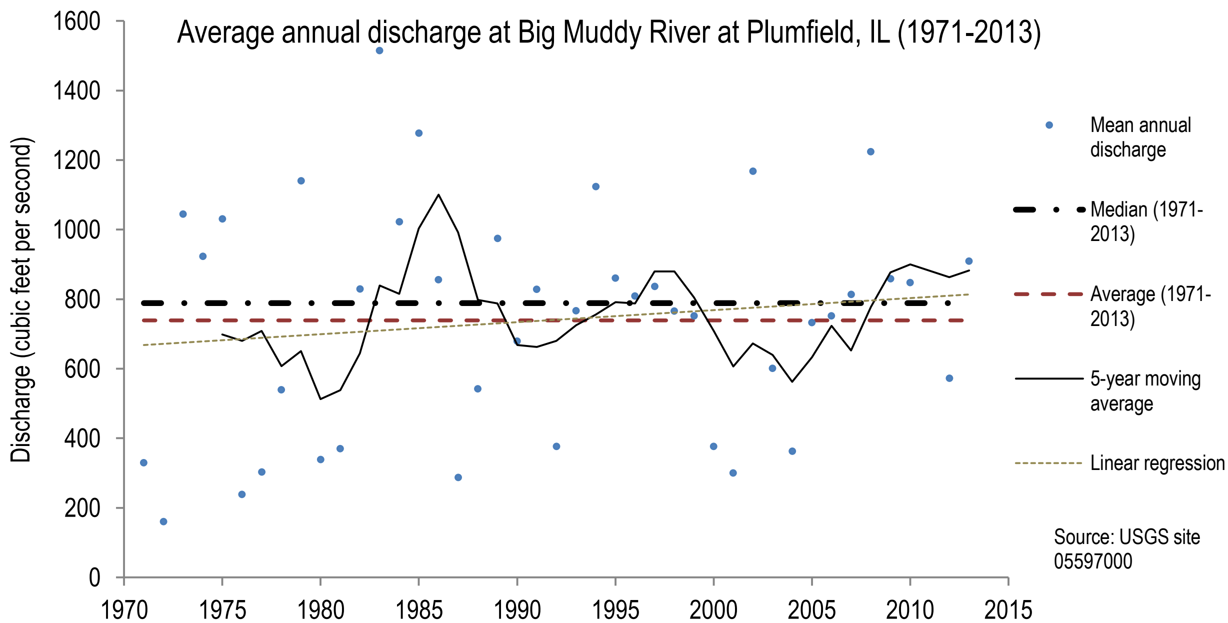


Figure 12 Average annual discharge at Big Muddy River at Plumfield, IL (USGS 05597000)

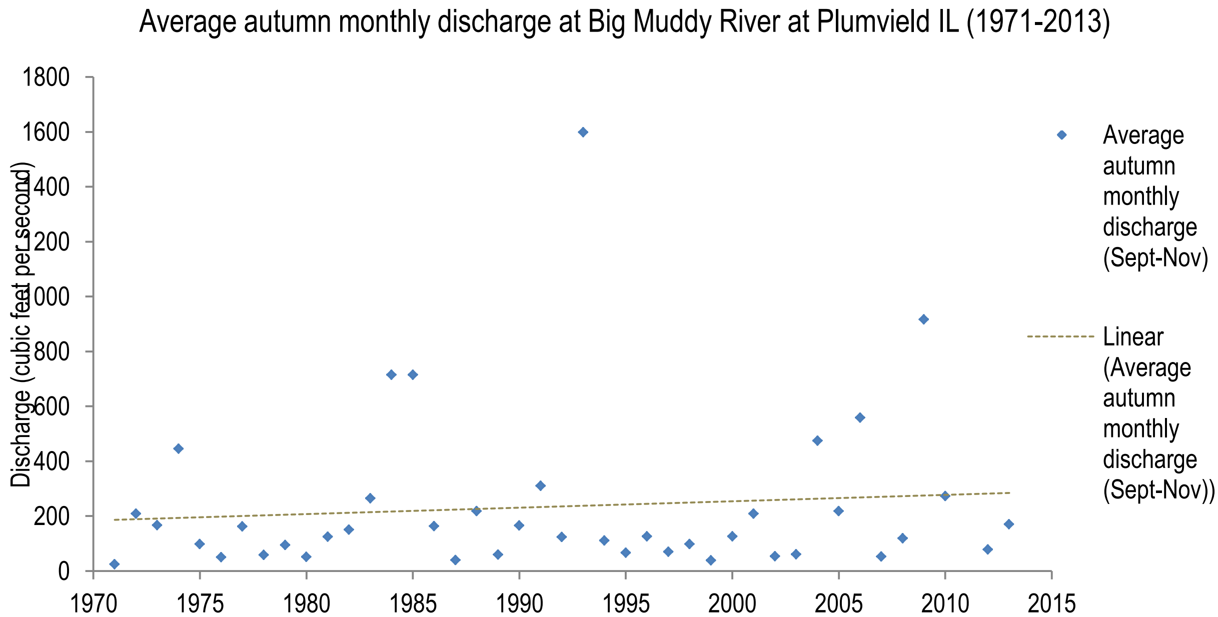


Figure 13 Average autumn monthly discharge at Big Muddy River at Plumfield, IL (USGS 05597000)

Potential implications of changes in climate trends

If general trends continue and southwestern Illinois receives more precipitation in autumn on average, more surface runoff will reach the Cache River at a higher rate during this season. Surface runoff may be drained directly to stream channels at a faster rate if artificial draining practices of surrounding agricultural lands increase in response to the overall wetter-conditions. This could mean more water recharge to depleted stream channels, but would also create increased opportunity for sediment, nutrient, and contaminant loading to the Lower Cache River Basin.

The continuation of higher average precipitation in autumn without a change in temperature could result in a more rapid increase in streamflows and groundwater recharge, and a general change in the seasonal distribution of water supply. Refuge staff may need to adjust drawdown management schedules accordingly. Wetlands of the Lower Cache River Basin may become deeper, or may be distributed over a wider area depending on localized sedimentation and topographic constraints. In either case, seasonal wetlands and streams will likely become more permanent throughout the year, which could cause ecosystem shifts within the Refuge. Species dependent on cycles of high and low water levels in these seasonal waters could either shift upland, or disappear from the area if certain areas shift toward more permanent water regimes. Seasonal and spatial changes in contaminant, nutrient, and sediment loading would also change with streamflow patterns. Assuming permanently inundated depressions expand in the area around the Refuge, larger areas will also be subject to potential contamination as sediments and contaminants settle out.

The overall effects of sustained, elevated water levels in Cache River wetlands could complicate water management within the Refuge. If water levels in the swamp are maintained at unnaturally high levels for prolonged periods, it could adversely impact the already-stressed natural hardwoods the area is known for, especially considering higher sediment loading rates that would accompany higher runoff volumes. In some areas, wetland habitats are likely already impounded for unnaturally prolonged periods by dams and water control structures, but if water levels are elevated as a consequence of higher precipitation rates, the possibility for restoring the hydrology in the form of regular flows and drawdown periods would become more complicated.

The Lower Cache Basin is very poorly drained, so excessive sediment, nutrient, and/or contaminant loadings experience a long residence time within the wetlands. Assuming elevated spring and summer temperatures persist with little change in precipitation inputs, water levels through these months may decline rapidly in localized areas of the Basin with little connection to groundwater, thereby increasing the concentrations of these pollutants and the threats they pose to wildlife that utilize these resources. Concentrated contaminates at frequently drawn-down or exposed areas may therefore adversely affect waterfowl health and/or foraging behaviors.

Water Resource Features

Water Management Units

CCNWR has roughly 914 acres of moist soil and wetland units within its boundaries (Figure 14, Figure 15, and Figure 16). In total, 707 acres of these water features are managed, and 207 acres are unmanaged.

CCNWR's herbaceous wetlands are generally managed as connected ecosystems and are purposed to provide foraging grounds for migrating birds, while accommodating other important wildlife. Management of Refuge impoundments generally attempts to time water level fluctuations with migratory bird arrival, with gradual, early flooding beginning in September and continuing through mid-December. Drawdown in the spring is also very gradual, beginning by late February. There is a 3-4 year rotation of disturbance for the moist soil units, and drawdowns are rotated among the units from year to year. These management cycles allow for the germination of important vegetation and encourage a diverse ecosystem. Additional details about water level management, species responses to drawdown, and the Refuge's general water resource objectives are provided in the HMP.

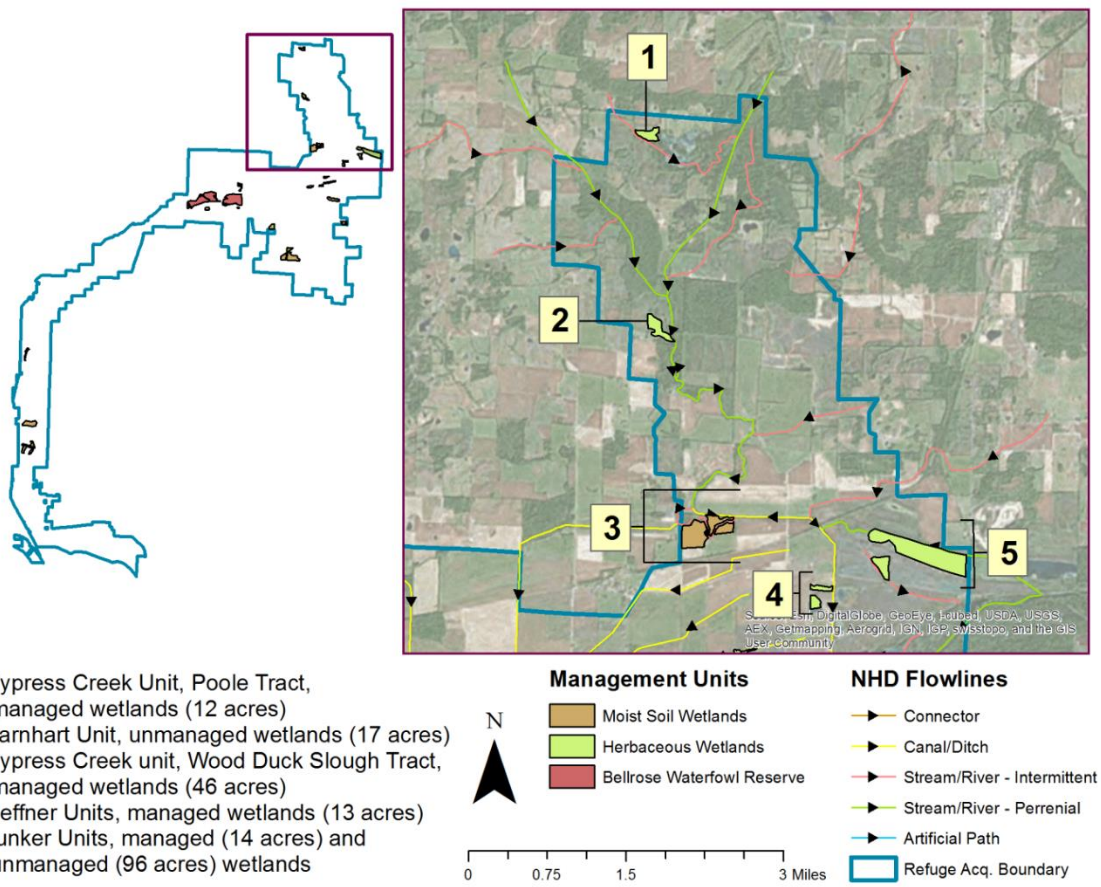
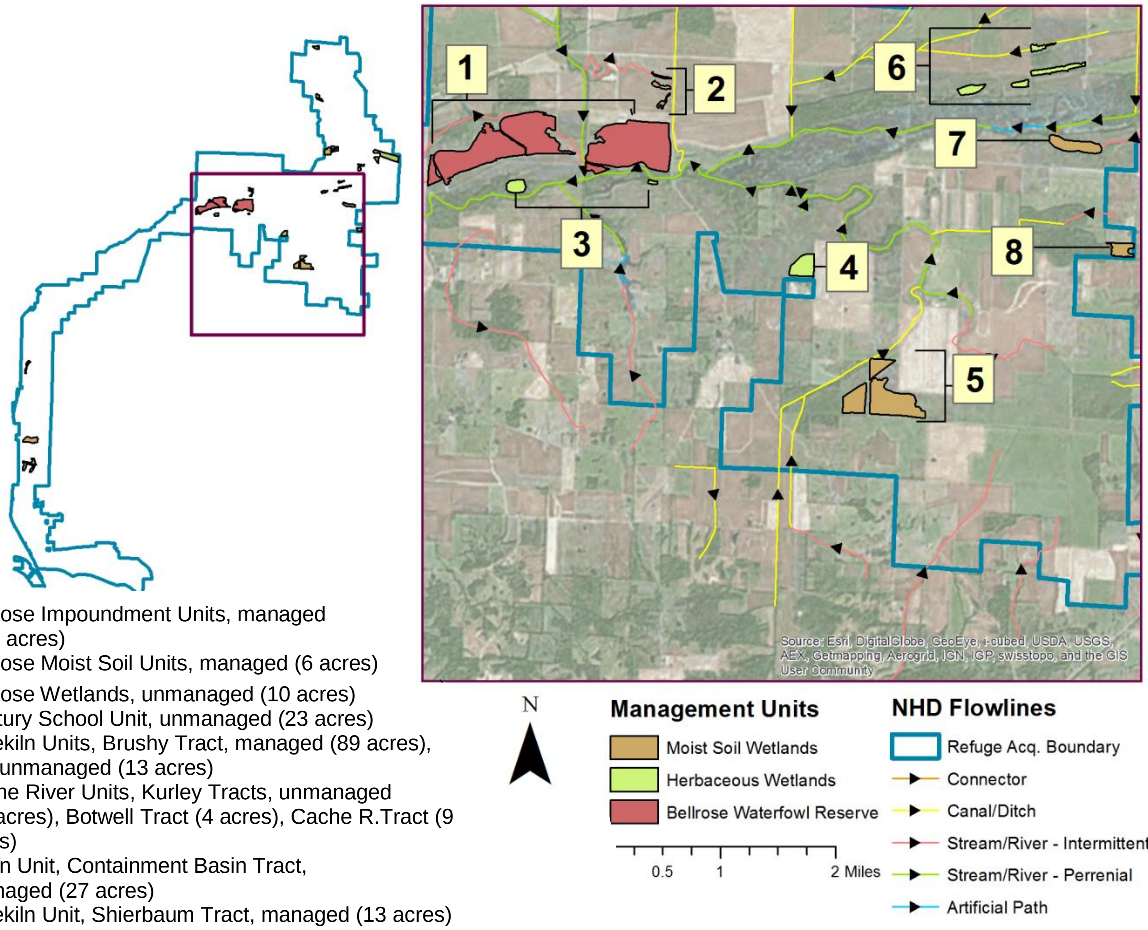


Figure 14 Water management units in the northern portion of CCNWR



1. Bellrose Impoundment Units, managed (370 acres)
2. Bellrose Moist Soil Units, managed (6 acres)
3. Bellrose Wetlands, unmanaged (10 acres)
4. Century School Unit, unmanaged (23 acres)
5. Limekiln Units, Brushy Tract, managed (89 acres), and unmanaged (13 acres)
6. Cache River Units, Kurley Tracts, unmanaged (16 acres), Botwell Tract (4 acres), Cache R.Tract (9 acres)
7. Basin Unit, Containment Basin Tract,
8. managed (27 acres)
9. Limekiln Unit, Shierbaum Tract, managed (13 acres)

Figure 15 Water management units in the central portion of CCNWR

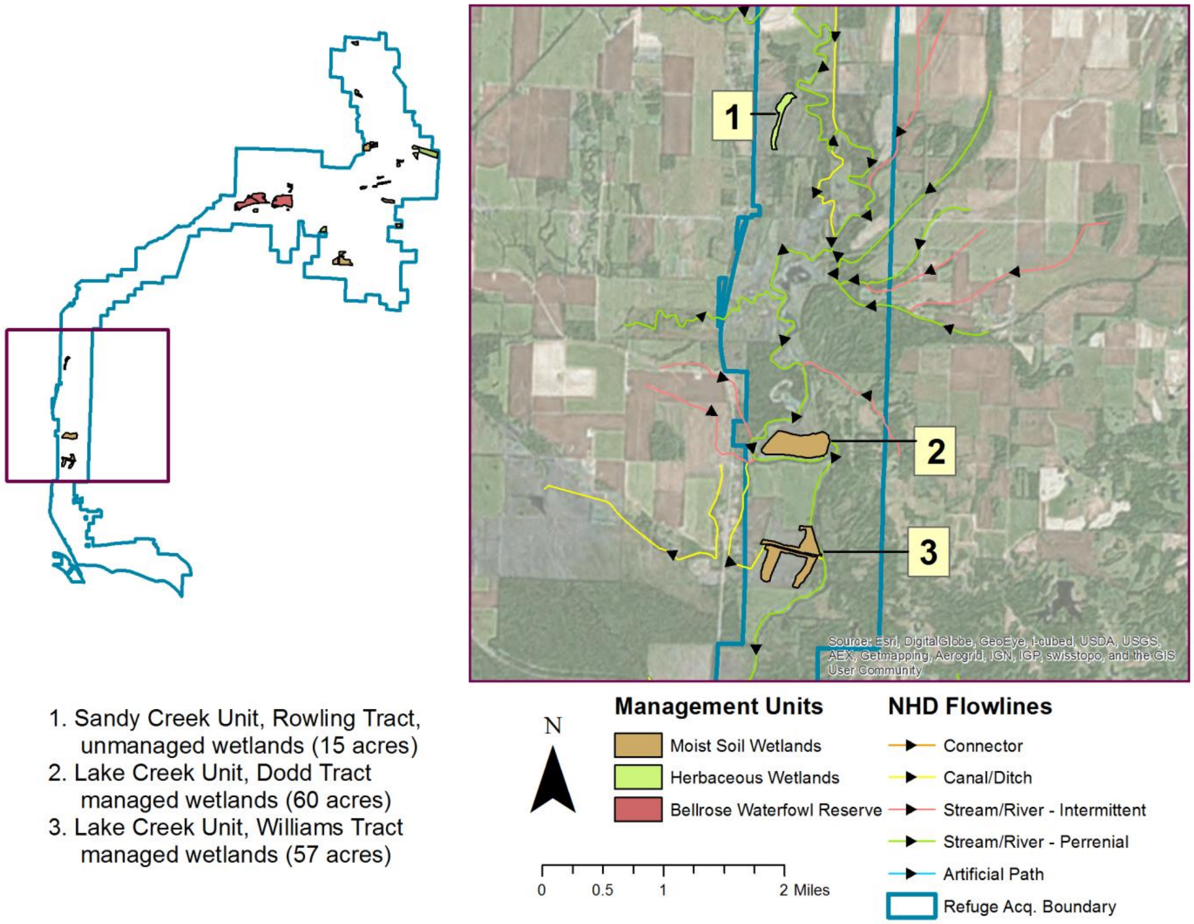


Figure 16 Water management units in the southern portion of CCNWR

Big Creek #2 Drainage District

A large portion of CCNWR intersects with the Big Creek #2 Drainage District (Figure 17), and the Refuge, District, and local farming community have established a working relationship to coordinate water management activities of shared resources. An environmental assessment completed in 1990 included provisions that the Service would meet relative to Drainage District activities. Included in the assessment was a letter from the regional director at that time to the Drainage District chair outlining the activities USFWS would undertake in ongoing cooperation with the Drainage District. The following is a summary of those conditions (USFWS 1990).

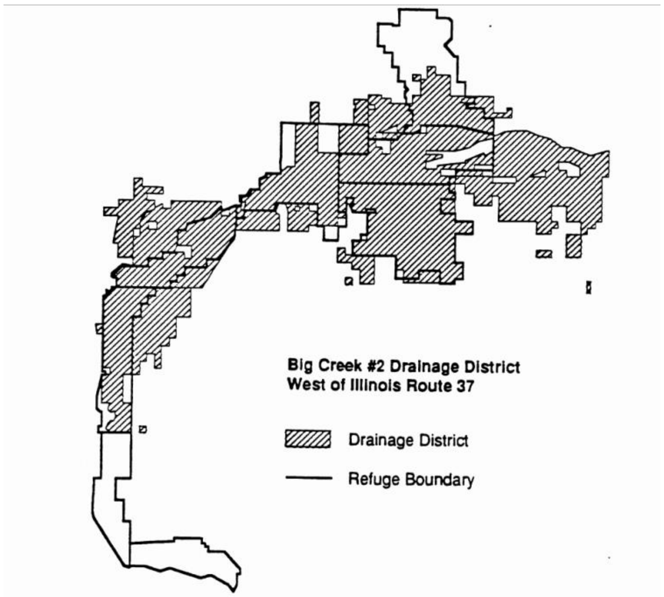


Figure 17 Portions of CCNWR property encompassed by Big Creek #2 Drainage district

USFWS is expected to clear debris jams affecting flow, prevent any activities that disrupt the drainage of private land in or adjacent to Refuge property, and avoid intervening with the District's activities outside of USFWS lands. Before CCNWR implements management activities that may cause artificial increases in the natural hydrology, it must confirm that impacts will be limited to Refuge property and/or tracts to be acquired in the future from a willing seller. Further, if activities cause permanent or temporary flooding that inhibits private landowners' use of their properties, just compensation is required.

Additional responsibilities of USFWS include:

- Annual inspections of the Drainage District's ditch network and laterals on USFWS lands.
- Mutual agreements with the District on repairs and maintenance projects.
- Obtaining permits and funding for repairs and maintenance of Refuge ditches.
- The maintenance and repair of the Cache River ditch system without reimbursement from the district.
- Allowing District access to the ditch system for maintenance if not performed by USFWS within a reasonable time. USFWS is not required to reimburse the District for these activities.
- Cooperation and consultation with the District and neighbors regarding maintenance of private ditches intersecting Refuge lands, permitting access thereto, and continued private rights following USFWS land acquisitions.
- Paying special assessments subject to availability of funds, in the event that Federal law is enacted enabling special assessments to be levied against US property. In such an event, USFWS will be relieved of all repair, maintenance, and financial obligations.

Limekiln Slough

The current hydrologic state of Limekiln Slough is not conducive to CCNWR's habitat goals. The Slough naturally had a stronger connection with the Lower Cache channel, but a dredge tailing now separates the two water features and Limekiln Slough has a longer water regime than it once did, resulting in a decline in the number of tree species and increased sedimentation in the localized area. Nearby private lands have lost agricultural value as a result, however some impacted neighbors utilize the wetland habitat on their lands for waterfowl hunting, and there are conflicting opinions about the potential changes to the local hydrology.

Preliminary surveys and investigation of the area indicate that low to moderate water levels upstream of the refuge are primary controlled by extensive beaver dam activity in the area. Some of these dams are constructed on the refuge and may need to be removed to impact agricultural drainage of upstream lands. High water levels along Limekiln Slough are controlled by the volume of runoff versus channel geometry, slope and roughness. Flooding on the Cache River can also reach stages that impound water across many lands adjacent to Limekiln Slough.

Sedimentation in the area around the mouth of Limekiln Slough is more likely to be driven by Cache River flows (greater sediment carrying capacity and watershed size) than Limekiln itself. To date, there is no sediment monitoring information or anecdotal evidence of sedimentation within the mouth area.

Surveys of the Cache River highlight additional considerations: 1) The Cache River channel is likely incised due to dredging, if so this, combined with possible sedimentation, reconnection may result in lower than historic water levels in the Limekiln Slough mouth area. 2) The spoil bank along the Cache River is tapered from east to west with bank heights being relatively low to the east and much higher to the west. Throughout, the banks are eroding latterly and appear moderately unstable. If left unaltered, the Cache River will eventually reconnect with the Limekiln Mouth. 3) If reconnection between the Cache River and Limekiln Mouth is pursued serious consideration needs to be given to neighboring land owners that may have different water level management objectives. For example, due to the slope of the floodplain (east to west) and the slope of the Cache River (east to west), a prime reconnection location may be at the western end of the Limekiln Slough mouth impoundment, however this area is in private ownership.

Several management options for reconnection between Limekiln Slough and the Cache River Channel are possible, including direct reconnection, the restoration of the historic Limekiln channel at its confluence with the Cache, the reconnection of the channels with the floodplain, the construction of various types of water control structures, or some combination of these options. However more information about the project site's hydrology is necessary to determine the most viable option.

Infrastructure and WCSs

Cypress Creek currently manages 30 different WCSs (Figure 18). These include 1 flap gate, 2 screw gates, 2 siphon inlet/outlets, 2 slide gates, and 23 stop logs.

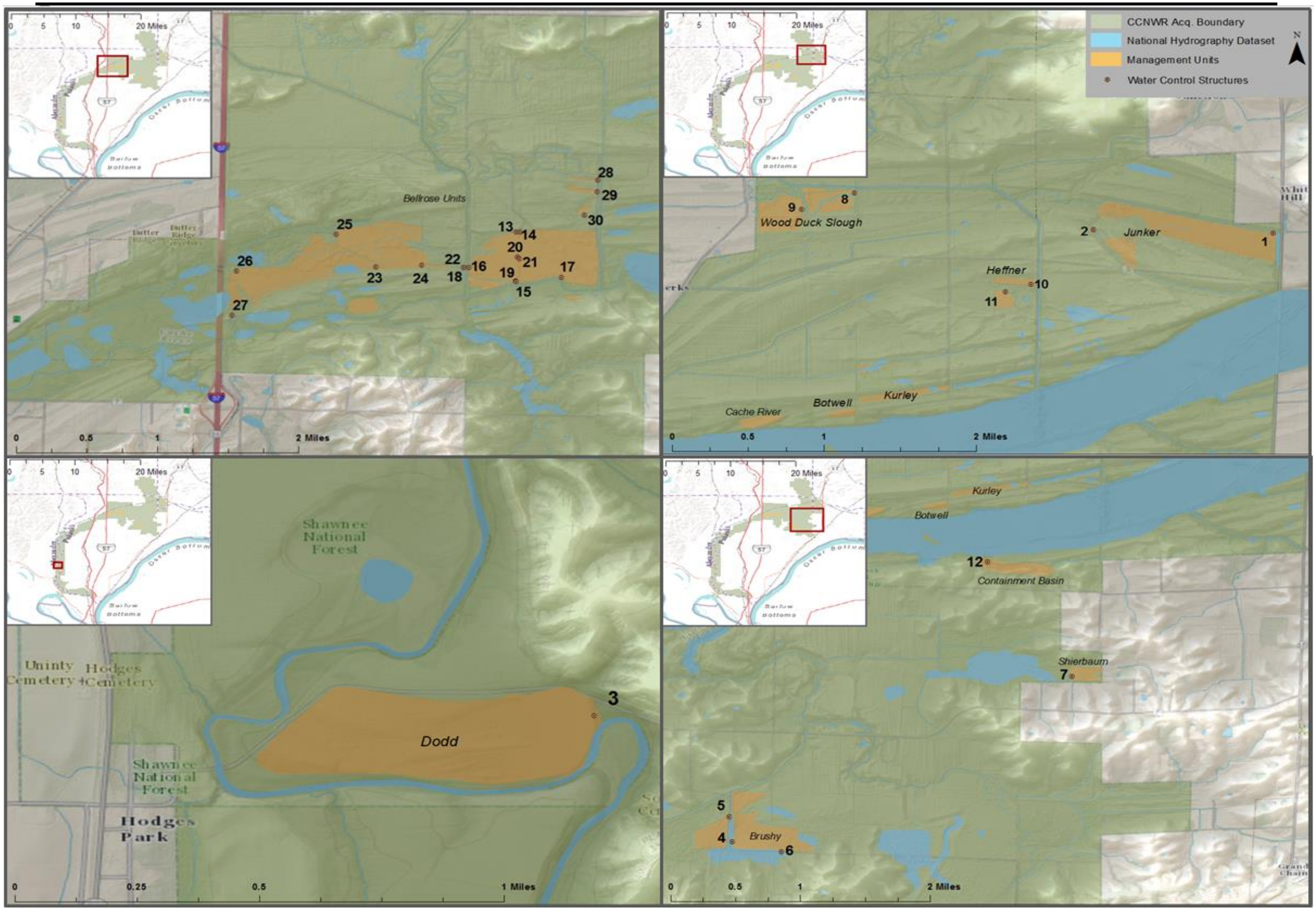


Figure 18 Water Control Structures at CCNWR

ID	Unit	Structure Description	x	y	Size
1	Junker 37	Stop Log (inline)	320814	4131842	24"
2	DU Junker	Stop Log	319297	4131913	24"
3	Dodd	Stop Log	299505	4115170	28"
4	Brushy East	Stop Log	315001	4125314	28"
5	Brushy West	Stop Log	314978	4125654	28"
6	Brushy Diversion	Stop Log	315488	4125168	28"
7	Schierbaum	Stop Log	318420	4127483	28"
8	Wood Duck Slough East	Stop Log	317285	4132383	28"
9	Wood Duck Slough West	Stop Log	316833	4132202	28"
10	Hefner (Borrow area)	Stop Log	318755	4131287	14"
11	Hefner (Main Impoundment)	Stop Log	318537	4131208	14"
12	Containment Basin	Stop Log	317612	4129055	48"
13	Bellrose Unit 1	Slide Gate	311478	4129290	48"
14	Bellrose main N	Stop Log	311514	4129287	31"
15	Bellrose Unit 1 Screw Gate	Screw Gate	311460	4128681	22"
16	Bellrose Siphon Inlet	Siphon Inlet	311043	4128854	40"
17	Bellrose Unit SE corner Inline	Flap Gate	311878	4128716	28"
18	Bellrose Slide Gate	Slide Gate	310994	4128858	17"
19	Bellrose 1 Main Structure	Stop Log	311467	4128668	48"
20	Bellrose Unit 1 cross levee west	Stop Log	311485	4128974	26"
21	Bellrose Unit 1 cross levee east	Stop Log	311500	4128955	21"
22	Bellrose Unit 2 Siphon Outlet	Siphon Outlet	310994	4128858	40"
23	Bellrose Unit 2 Main Structure	Stop Log	310197	4128881	48"
24	Bellrose Unit 2 East inline	Stop Log	310611	4128897	28"
25	Bellrose Unit 2 NW	Stop Log	309841	4129295	28"
26	Bellrose Unit 3 main structure	Stop Log	308929	4128859	48"
27	Bellrose Unit 3 Screw gate	Screw Gate	308873	4128306	36"
28	Bellrose Ag Unit North	Stop Log	312235	4129915	24"
29	Bellrose Ag Unit Central	Stop Log	312226	4129773	24"
30	Bellrose Ag Unit South	Stop Log	312104	4129487	24"

Table 1 Water control structures at CCNWR

NWI

Southern Illinois formerly supported approximately 250,000 acres of cypress-tupelo swampland, much of which were destroyed by logging, draining, and agricultural activities (IDNR 1997). The Cache River Basin still, however, holds approximately 91% of Illinois' swamp and wetland habitat. The forested wetland fragments that remain within the Lower Cache River Watershed provide valuable hydrologic and ecologic functions to the region, but are still at risk because of reduced flow to the lower Cache watershed and aggradation effects.

CCNWR's remaining wetlands can be described with the National Wetlands Inventory (NWI), which is an extensive, ongoing survey by the U.S. Fish and Wildlife Service of aquatic habitats across the United States. According to the classification within CCNWR's acquisition boundary, most of the mapped units are palustrine systems, which are dominated by trees, shrubs, emergent vegetation, moss, or lichens (see Appendix B). Most of these wetlands are characterized by woody, broad-leaved, deciduous vegetation at least 20 ft in height and demonstrate either a seasonal, temporary, or semi-permanently flooded water regime.

In terms of general wetland types, the NWI classified approximately 84% of the acquisition boundary as freshwater forested/shrub wetland. Freshwater emergent wetland accounts for roughly 9% of the area, while 5% is riverine, 2% is freshwater pond, and less than 0.5% is classified as lake. Additional information associated with wetlands relevant to the Refuge can be found in Appendix B.

NHD

The National Hydrography Dataset (NHD) is a vector geospatial dataset including information about the nation's lakes, ponds, rivers, streams, and other water features, part of the USGS's National Map. Within the acquired boundary, the flowpaths identified by the NHD can be broken down based on type (Table 2). The majority of the flowpaths were considered artificial paths or stream/river features.

Important named features identified by the NHD within the CCNWR acquisition boundary include the Cache River (40.9 miles), Mill Creek (9.2 miles), Cypress Creek (6.3 miles), the Mississippi River (3.9 miles), Big Creek (3.8 miles), Cypress Slough (3.5 miles), Cottonwood Slough (3.3 miles), Little Creek (3.3 miles), Adds Branch (2.8 miles), Sandy Creek (2.0 miles), Hogskin Creek (1.9 miles), Boar Creek (1.7 miles), Jackson Creek (1.6 miles), Pulaski Slough (1.4 miles), and Indian Camp Creek (1.3 miles). There is a total of roughly 204 miles of NHD flowpaths within the CCNWR acquisition boundary, approximately 142 miles of which are unnamed. Figure 19 presents important named water features within CCNWR's contributing HUC-8 and relevant areas of the downstream HUC-8. A more comprehensive inventory of relevant information, including unnamed features, will be available through the WRIA database (https://ecos.fws.gov/wria/)

The NHD provides an approximate representation of general water flow and does not necessarily reflect actual conditions. Further, the NHD's inventory of "named features" is not necessarily all-inclusive, and some features may be mis-categorized. You-Be Hollow and Beech Hollow are not named in the NHD, but have been included in the inventory and figure below.

Description	FCode	Acquisition Boundary		Fee Boundary	
		Sum (miles)	%	Sum (miles)	%
Connector	33400	0.67	0.33%	0.19	0.18%
Canal/Ditch	33600	0.00	0.00%	0.00	0.00%
Stream/River - Intermittent	46003	109.06	53.50%	50.61	49.35%
Stream/River - Perennial	46006	39.78	19.51%	22.43	21.87%
Artificial Path	55800	54.35	26.66%	29.33	28.60%
Total		203.85		102.55	

Table 2 NHD flow type information for CCNWR

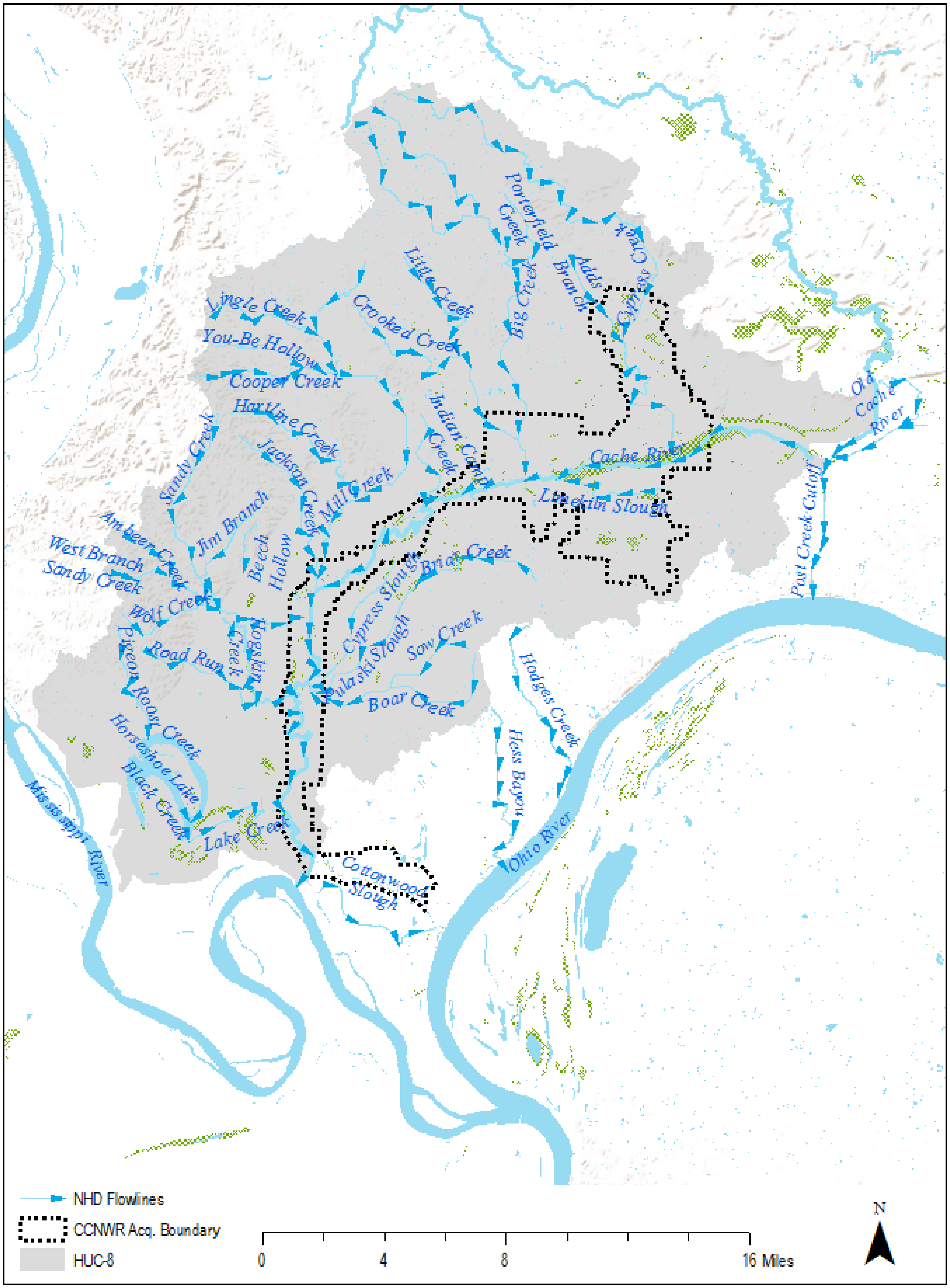


Figure 19 Named NHD flowlines relevant to CCNWR (unnamed NHD features excluded).

Aquifers

The Cache River Watershed is situated at the intersection of several major aquifer systems. The Ozark Plateaus aquifer extends over the northern portion of the Refuge, the Southeastern Coastal Plain aquifer system is in the west, and the Mississippi River Valley alluvial aquifer is present in the south (USGS 2003). The principal aquifers are composed of carbonate-rock, semi-consolidated sand, unconsolidated sand and gravel, and other rocks (Figure 20, USGS 2014). A description of the Cache River Basin's aquifer systems relevant to the Refuge is included in the HGM (Heitmeyer and Mangan, 2012):

> *"The CRV is underlain by sand and gravel aquifers, most of which are 20-50 feet below the surface and are annually recharged from the Mississippi, Ohio, and Cache Rivers and from downslope discharge from the upland aquifers in the Shawnee Hills. The potentiometric surface of the alluvial aquifer is near the ground surface in many locations. Deeper aquifers of Paleozoic age and unconsolidated aquifers of Mesozoic and Cenozoic age also are present (Luckey 1984, Woerner et al. 2003). The older McNairy aquifer ranges from 0 to 600 feet thickness. This aquifer has a large artesian head and low iron and hardness concentration (Luckey 1984). The Mounds, Henry, Equality, and Cahokia formations often lie above the McNairy material and are of variable depth and quantity; most are at least 150 feet below the floodplain surface."*

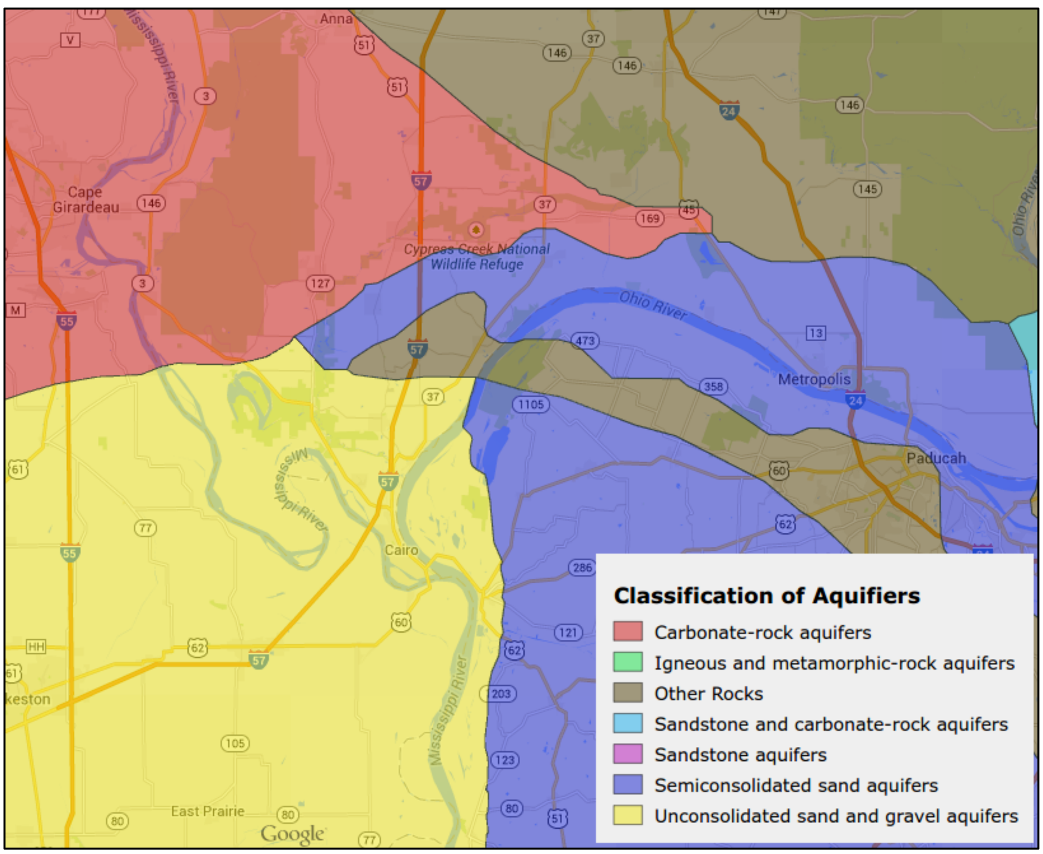
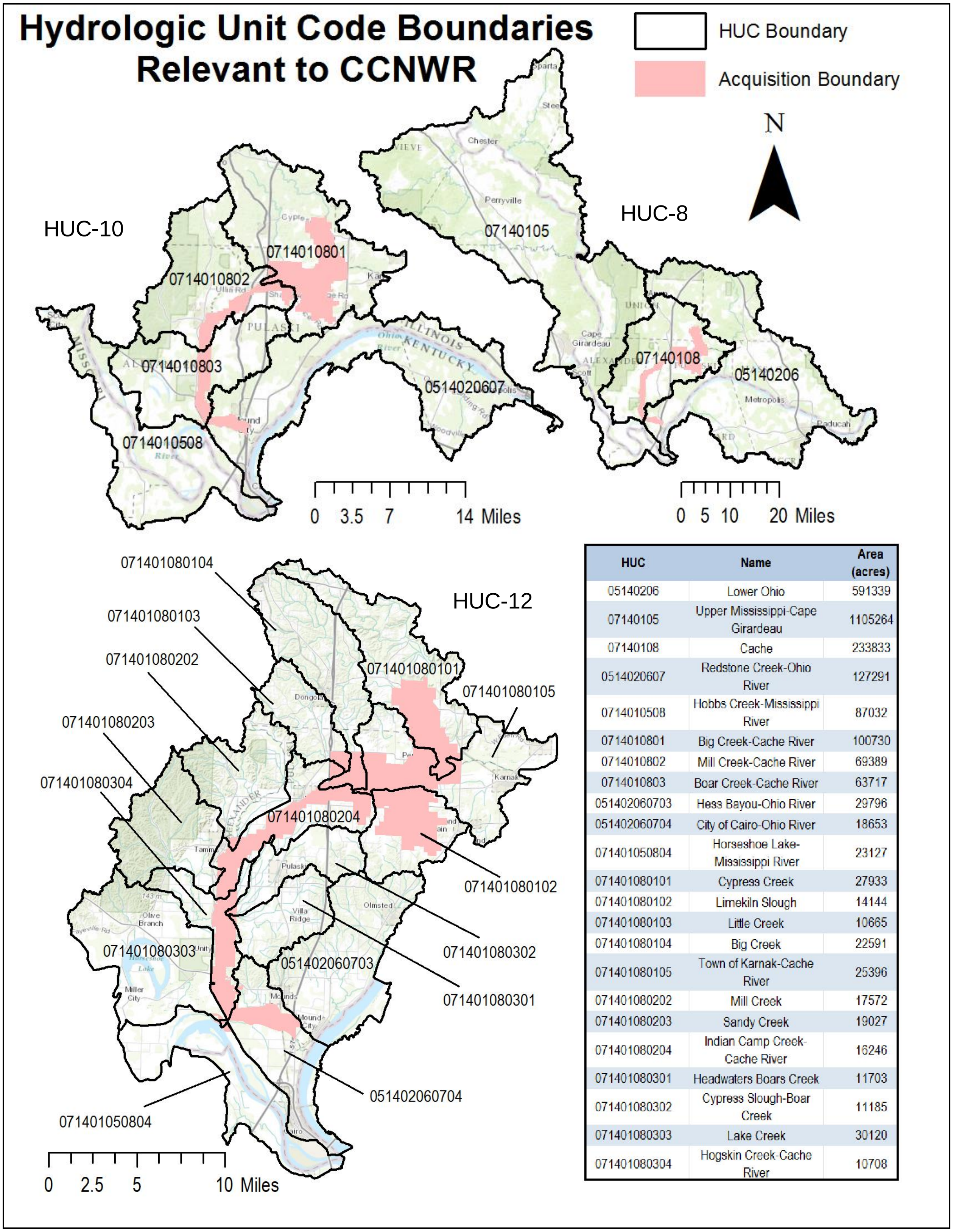


Figure 20 General composition of aquifers underlying CCNWR

Water Resource Monitoring

Water resource monitoring information is described in the context of the Refuge's designated Region of Hydrologic Influence (RHI), which is the relevant region for the collection of water quality and quantity information. In this case, CCNWR's RHI is its intersecting 10-digit Hydrologic Unit Code (HUC-10) boundary. HUCs are used to designate watersheds of various sizes and often represent the initial aggregate level of water quality and quantity information available from a variety of agencies. HUC boundaries are a successively smaller classification system based on drainage, adapted from Seaber et al. (1987).

CCNWR is part of two different 8-digit HUCs, including the Cache River and Lower Ohio drainages. The Refuge is also directly downstream of the Upper Mississippi-Cape Girardeau HUC-8. Five HUC-10s, including Redstone Creek-Ohio River, Hobbs Creek-Mississippi River, Big Creek-Cache River, Mill Creek-Cache River, and Boar Creek-Cache River, represent the RHI for CCNWR (Figure 21). The smaller HUC-12 boundaries are also evaluated herein, if they contained the primary Refuge source waters.



HUC	Name	Area (acres)
05140206	Lower Ohio	591339
07140105	Upper Mississippi-Cape Girardeau	1105264
07140108	Cache	233833
0514020607	Redstone Creek-Ohio River	127291
0714010508	Hobbs Creek-Mississippi River	87032
0714010801	Big Creek-Cache River	100730
0714010802	Mill Creek-Cache River	69389
0714010803	Boar Creek-Cache River	63717
051402060703	Hess Bayou-Ohio River	29796
051402060704	City of Cairo-Ohio River	18653
071401050804	Horseshoe Lake-Mississippi River	23127
071401080101	Cypress Creek	27933
071401080102	Limekiln Slough	14144
071401080103	Little Creek	10665
071401080104	Big Creek	22591
071401080105	Town of Karnak-Cache River	25396
071401080202	Mill Creek	17572
071401080203	Sandy Creek	19027
071401080204	Indian Camp Creek-Cache River	16246
071401080301	Headwaters Boars Creek	11703
071401080302	Cypress Slough-Boar Creek	11185
071401080303	Lake Creek	30120
071401080304	Hogskin Creek-Cache River	10708

Figure 21 Hydrologic Unit Code Boundaries relevant to CCNWR

The WRIA identified historical and ongoing water resource related monitoring on or near the Refuge. Ground and surface water stations were considered relevant if located within the Refuge's HUC-10 and/or drainage areas adjacent to Refuge property. Relevant sites were evaluated for applicability based on location, period of record, extent of data, sampling parameters, trends, and date of monitoring. Water resource datasets collected on the Refuge can be categorized as water quantity or water quality monitoring of surface or groundwater.

Water quantity monitoring typically involves measurements of water level and/or volume in a surficial water body or subsurface aquifer. Water quality can include laboratory chemical analysis, deployed sensors or biotic sampling such as fish assemblages or invertebrate sampling. Biotic sampling is often used as an indicator of biological integrity, which is a measure of stream purpose attainment by state natural resources management organizations.

Potential water quality threats may be identified by comparing monitoring data with recommended standards. The EPA developed technical guidance manuals and nutrient criteria for various types of waters specific to different ecoregions. Those developed for rivers/streams and lakes/reservoirs for ecoregion IX are summarized below (Table 3; EPA, 2000).

	Lakes and Reservoirs	Rivers and Streams
TP µg/L	20	36.56
TN mg/L	0.36	0.69
Chl a µg/L	4.93	0.93
Secchi (m)	1.53	5.7

Table 3 EPA recommended water quality criteria for Southeastern Temperate Forested Plains and Hills (Ecoregion IX; Level III)

In addition, the Illinois Pollution Control Board promulgates water quality standards in the state. Sections 302 and 303 of Illinois Administrative Code (IAC) include standards relevant to lakes and streams. Derived water quality criteria are available from the Illinois EPA website (http://www.epa.state.il.us/water/water-quality-standards/water-quality-criteria-list.pdf).

Several resources offer water quality and quantity datasets relevant to Refuge waters, and were utilized in compiling data for the WRIA. For example:

- Data for historical sampling locations can be retrieved through the EPA STORET (STOrage and RETrieval; http://www.epa.gov/storet/) database. This data warehouse is a repository for water quality, biological, and physical data used by state environmental agencies, EPA and other federal agencies, universities, and private citizens.
- Water quality and quantity data for active and inactive monitoring sites can also be accessed from the USGS National Water Information System (NWIS) database (http://www.waterqualitydata.us/).
- The ISWS has initiated several applicable water quality monitoring programs, including its Interagency Pilot Monitoring Project (1999-2003). Associated stage, discharge, and sediment data measured from April 2000 to September 2003 are available on the ISWS webpage (http://www.sws.uiuc.edu/wss/wmd/PILOTproject.asp).

- Two sites relevant to the Refuge are included in the ISWS's Water and Atmospheric Resources Monitoring Program (WARM), and extensive in-stream sediment data for project sites #378 and #513 (http://www.isws.illinois.edu/warm/sediment/psdata.asp) at the Cache River are available. Particle size distribution data for these sampling sites are also accessible (http://www.isws.illinois.edu/warm/sediment/psdata.asp).

1.8 Water Monitoring Stations and Sampling Sites

The WRIA identified 12 monitoring sites considered applicable to the Refuge's water resources (See Appendix C). Ten of these sites are surface water monitoring points, and 2 are groundwater monitoring points. The locations of especially relevant USGS monitoring points with extensive datasets are depicted below (Figure 22).

Another list was compiled, including 73 sites that are relevant but not necessarily directly applicable to the resources of concern or that are currently inactive.

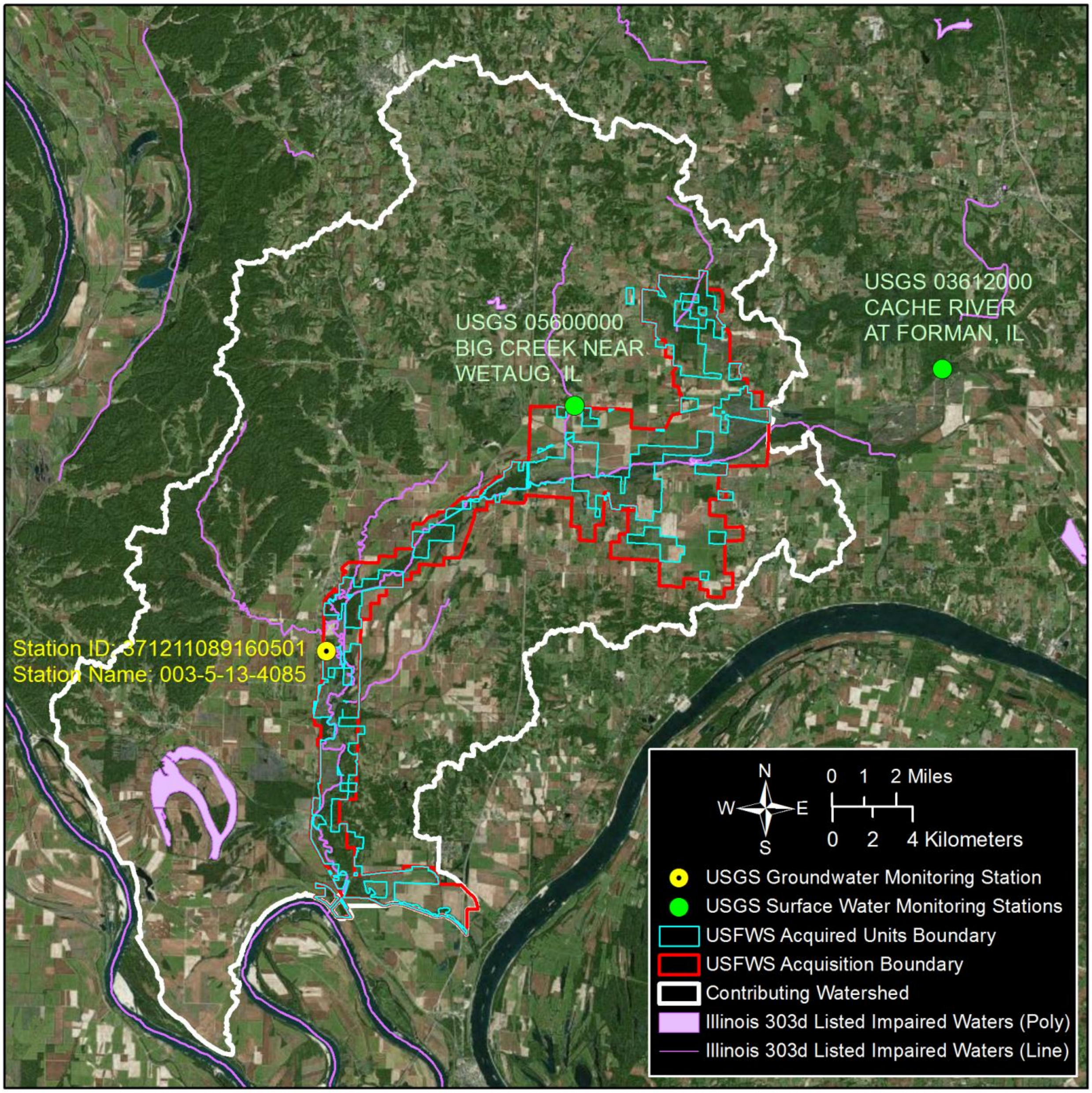


Figure 22 Locations of USGS gage stations with extensive datasets relevant to Refuge water resources

1.9 Surface Water Quantity

General Flood Patterns

The primary water inputs to the Lower Cache River Basin include precipitation, groundwater flow, tributary flows primarily from Cypress Creek, Big Creek, and Limekiln Slough, as well as surface floodwaters from the Upper Cache, Ohio River, and Mississippi Rivers. During high flow events, floodwaters often back up into the Cache River's steeper tributary channels, and flood hydrographs of the lower Cache River quickly rise before receding slowly, since outflows are extremely slow through this low-gradient, poorly-drained reach (IDNR 1997).

The Lower Channel, because of its proximity to the confluence of the Ohio and Mississippi Rivers, experiences increasing risks of flooding during backwater flood conditions and extremely high discharges of the Ohio and Upper Cache Rivers. While Refuge water levels have always been controlled to some degree by the behavior of the two major rivers that border it, Mississippi River backwaters influenced the hydrology of the Lower Cache River more frequently prior to alteration—during spring and summer of most years (Heitmeyer and Mangan 2012).

Currently, the 100-year flood of the Upper Cache and Ohio Rivers flow through the Karnak Levee breach and cause excessive flooding throughout the Lower Cache River (Demissie et al. 2010). This can occur simultaneously with the occasional backwater floods from the Mississippi River, resulting in excessively flooded areas and a longer-than-natural water regime within the lower reaches. This creates opportunity for the transport of nutrients, sediments, pesticides, salts, hydrocarbons, metals, and other contaminants sourced from the Cache River Watershed as well as the significantly larger Mississippi and Ohio drainages.

USGS Gage Datasets

The subsections below evaluate discharge data collected from two primary water inputs for the Refuge: the Cache River and Big Creek. Results are discussed with consideration for hydroclimate findings previously discussed for Big Muddy River (see HCDN discussion under Long Term Climate Trends section). It is important to note that the periods of record for both the Cache River and Big Creek datasets began after the watershed had already been extensively altered by drainage and channelization activities, such as the construction of Post Creek Cutoff in 1915.

No significant trends in average annual and peak streamflow were detected in this analysis for Big Muddy, Big Creek, and Cache Rivers. This finding is somewhat surprising considering average annual precipitation data suggests recent wetter conditions, especially in the fall and spring, and streamflow is expected to be relatively sensitive to changes in precipitation in this part of Illinois (Sankarasubramanian et al. 2001). Conversion of forestland to agricultural land, channelization, and the loss of floodplain due to levees and infrastructure also typically facilitate increases in streamflow, so it is particularly surprising that no clear indications of streamflow responses were detected in this highly altered region. For unclear reasons, streamflow patterns over the entire area have not been responding as expected to recent precipitation trends. Perhaps infiltration across the watershed has increased to some extent, but in any case, a smaller quantity of runoff is reaching the stream channels despite general increases in average annual precipitation, and this observation requires additional investigation.

Though this analysis did not uncover any clear trends, this does not necessarily mean that one does not exist, or that streamflow might not respond to precipitation and alteration changes in the future. A more detailed statistical evaluation of other parameters, such as minimum flows, or of discharge datasets over different temporal scales, might more effectively reveal underlying trends, or reinforce evidence for a lack thereof.

If streamflow in this region is truly not responding significantly to changes in precipitation patterns, it may be important to investigate potential reasons why to more-accurately anticipate how things could change in the future. Specifically, runoff, evapotranspiration, and groundwater dynamics are key elements to assess in this context.

Cache River

Two USGS stream gage stations provide comprehensive information on water quantity for the Refuge. USGS 03612000 Cache River at Forman, IL drains approximately 244 square miles. Discharge at this station has typically peaked between March and April and is lowest sometime between August and October (Figure 23 and Figure 24), which coincides with high and low seasons for precipitation, suggesting a strong connection between rainfall and surface water runoff. Typically, most floods occur in March, April, and May in this area, and floods are less common through the winter months (Bouska et al. 2012). Peak annual streamflow has been particularly high in recent years, with record-setting events in 2008 and 2011 (Figure 25). Though the dataset indicates a very slight increasing trend in peak annual streamflow over time, and two of the most extreme events have been very recent (2008 and 2011), this increase is not statistically significant over the entire period of record. There is also no trend in average annual discharge (1923-2013) at this site. Perhaps some clear differences may have been observed if the period of record began prior to the construction of Post Creek Cutoff

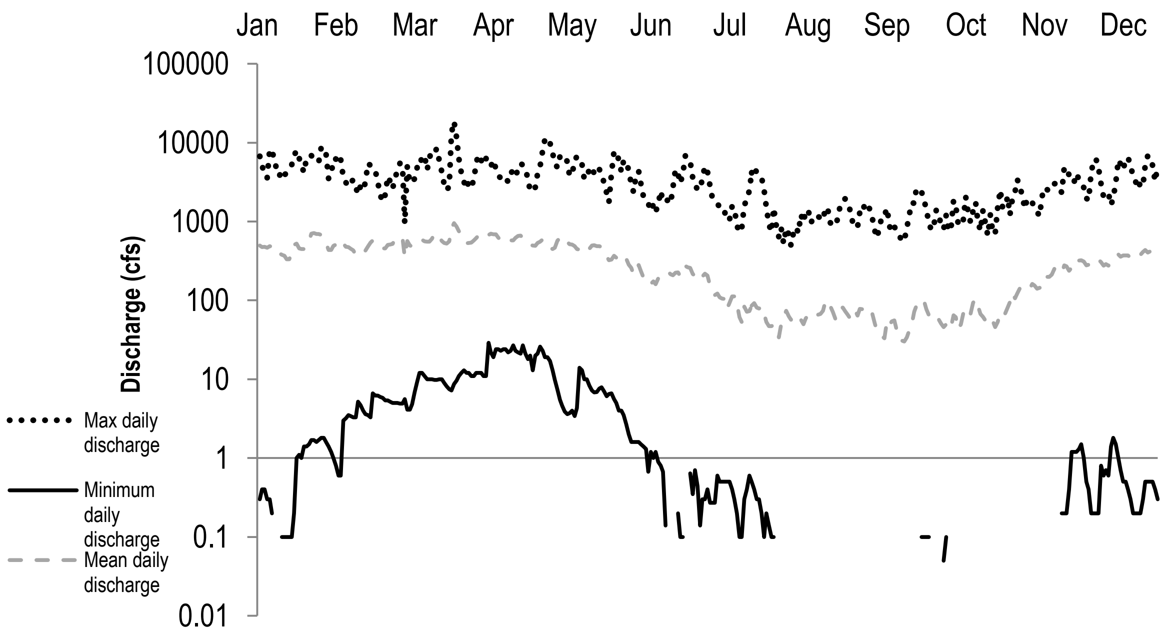


Figure 23 daily discharge stats for Cache River at USGS 03612000

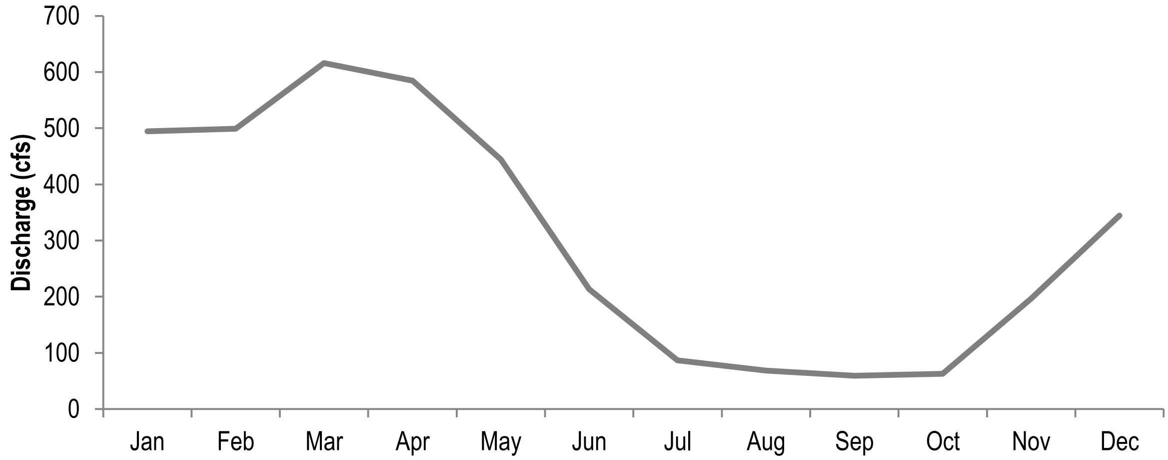


Figure 24 Monthly mean discharge at USGS 03612000 (Cache River at Forman, IL) 1922-2011

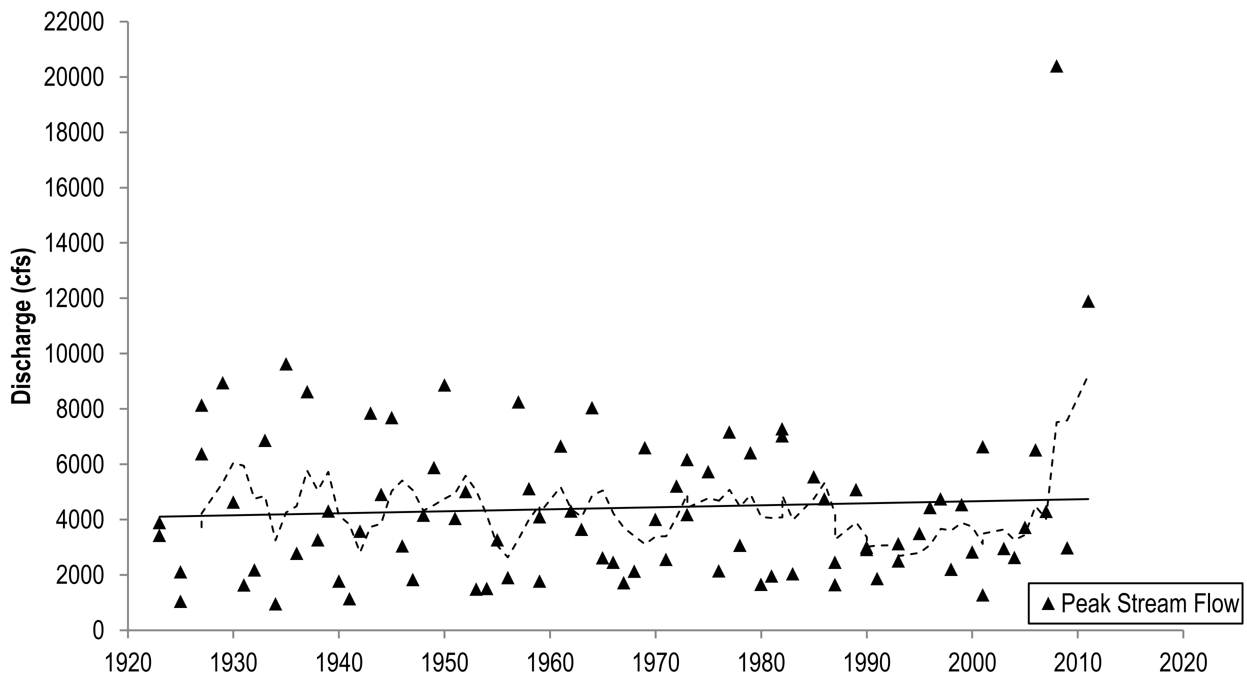


Figure 25 Peak streamflow data from USGS site 3612000 (Cache River at Forman, IL) from 1923-2011

Big Creek

USGS 5600000 (Big Creek near Wetaug, IL) provides additional water quantity data directly relevant to the Refuge's water budget. This station drains approximately 32 square miles. Average discharges at this gage have historically been lowest in August through October and highest in March (Figure 26), though minimum daily discharges appear to peak in the month of April or May (Figure 27) based on data from the '40s-'70s. Annual peak streamflow data shows an unexpected decreasing trend over the period of the record, however a few recent extreme events (2008 and 2011) brought a sharp increase in the 5-year moving average (Figure 28). Recent data (since 1971) for alternative statistics, such as average annual daily discharge, are not available, so further-evaluation of underlying trends was not possible for this analysis.

Annual peak streamflow information from this gage conflicts with some of the findings from the WRIA climate analysis. While the wide range in flows exhibited at this gage site is not uncommon for small basins in this region, this watershed is unique in that its low-flow events are consistently sustained (Demissie et al., 2001). Perhaps baseflow and groundwater dynamics are part of the reason high-discharge events at this site does not appear to be overly-responsive to increases in annual precipitation.

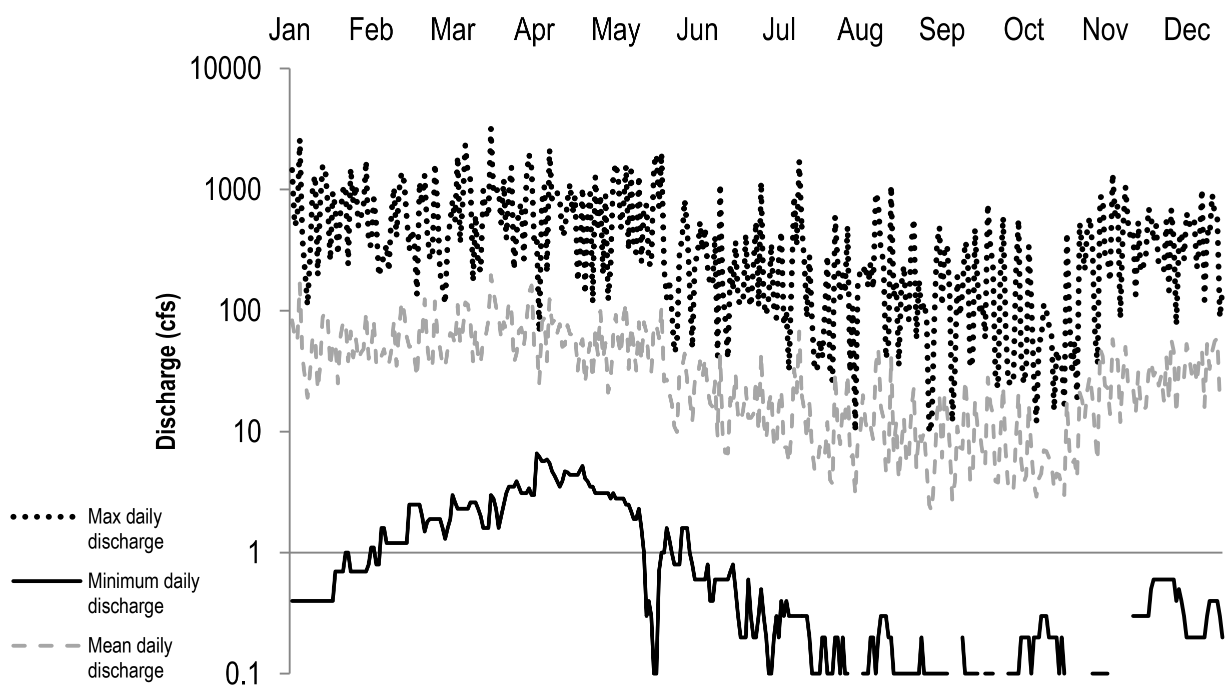


Figure 26 Graph of daily discharge stats from USGS site 5600000 (Big Creek near Wetaug, IL) 1941-1971

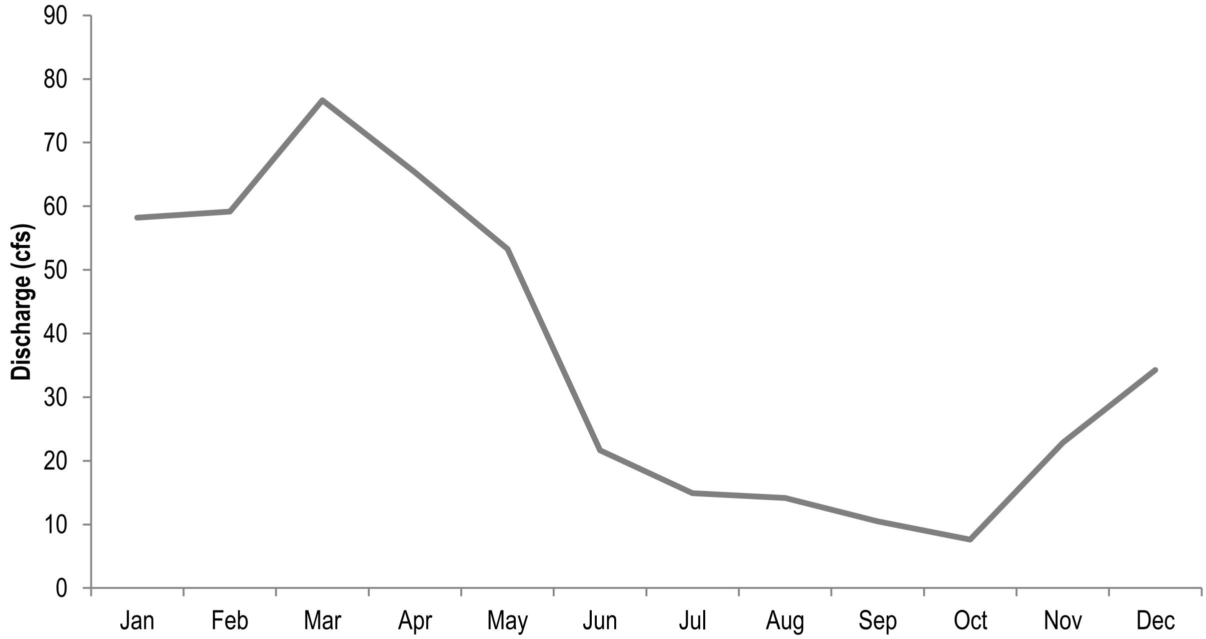


Figure 27 Monthly mean discharge at USGS 05600000 (Big Creek near Wetaug, IL) 1940-1971

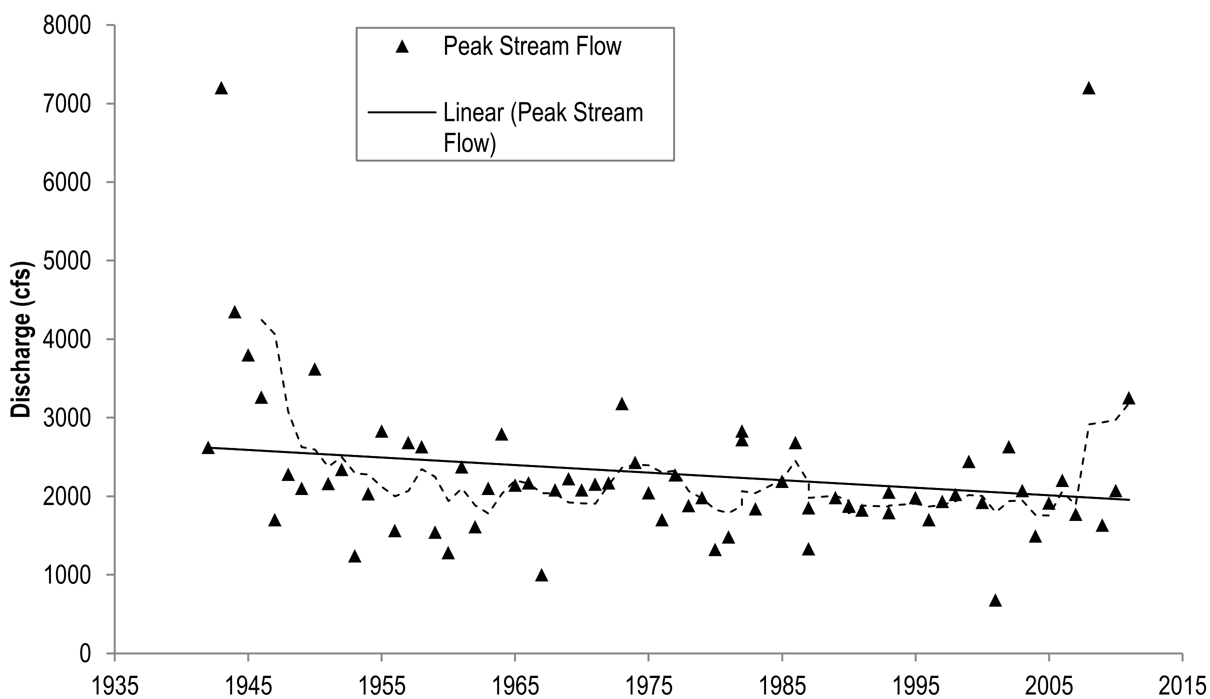


Figure 28 Peak annual streamflow data from USGS 05600000 (Big Creek near Wetaug, IL) 1942-2011

Flood Frequencies

The USGS included gages 05600000 and 3612000 in a report estimating flood-peak discharge magnitudes and frequencies for rural streams in Illinois (USGS, 2004). A river's "flood frequency" is the probability of reaching a particular maximum discharge for a given location on the River in any given year. For example, the 5-year return interval has a 1 out of 5 (20%) probability of occurring in a given year, and a 100-year return interval has a 1% chance of occurring in a given year. These calculated return intervals can be an underestimate, due to changing underlying flood pressures. Details on drainage basin statistics and flood frequencies from this report are listed below in Table 4 and Table 5.

Flood frequencies for the Cache River have likely changed since this report. Two of the largest floods on record for the Cache River occurred after 2004, and one of these was in the 500-year-flood range based on the information below.

Station	Total Drainage Area (mi2)	Main Channel Slope (ft/mi)	Basin Length (mi)	Basin Width (mi)	Average Permeability (in/hr)
USGS 5600000 - Big Creek at Wetaug, IL	32.2	14.93	12.09	2.66	1.461
USGS 3612000 - Cache River at Forman, IL	244	2.99	27.12	8.99	1.242

Table 4 Drainage basin characteristics for USGS 5600000 and USGS 3612000 (USGS, 2004)

USGS 5600000 - Big Creek at Wetaug, IL						
Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
2090	2770	3270	3930	4460	5020	6470
2680	4160	5220	6620	7710	8820	11500
2100	2810	3330	4030	4600	5190	6730
USGS 3612000 - Cache River at Forman, IL						
Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
3640	5870	7480	9650	11300	13100	17400
6090	8710	10500	12800	14500	16200	20300
3670	5910	7540	9720	11400	13200	17500
Three estimates are listed: the values in the top row are from at-site frequency curves; values in the middle row are from regional regression equations, values in the bottom row are obtained by weighting the at-site and regional regression frequency curves. Q values are in cfs.						

Table 5 Flood frequency estimates for USGS 5600000 and USGS 3612000 (USGS, 2004)

1.10 Groundwater elevation

While surface water runoff, precipitation, and backwater flooding are important drivers in water elevations for the Refuge, groundwater flow also has a relatively strong influence. Stratified, porous sand layers in area soils cause groundwater levels of the Refuge to emulate levels of the Cache, Mississippi, and Ohio Rivers, as discussed in the HGM (Heitmeyer and Mangan 2012):

"…river levels that are above floodplain land elevations can create a hydraulic pressure head sufficient to cause groundwater to move from the Mississippi and Ohio Rivers into and through subsurface land/gravel layers and discharge into CRV areas. It is common for certain wetland depression such as point bar swales next to the Ohio River to be shallowly flooded by groundwater discharge when Ohio River levels rise even if no local/regional precipitation has occurred for some time."

Several freshwater springs occur within the Cache River Basin, at least 25 of which occur near the Cache River channel itself (Heitmeyer and Mangan, 2012, Phillips 1994, Phillips 1996). One of these is located on the Cypress Creek unit of Cypress Creek NWR, approximately six miles north of the Cache River, and empties into a slough in Hogans Bottom, which is located in the northern portion of CCNWR. Shallow groundwater seeps are a potential source of nutrients as much of this water comes from the infiltration of rainfall on highly fertilized agriculture fields in the watershed (Coffey et al. 2012).

The 30-ft monitoring well near Sandy Creek in Alexander County has the most extensive groundwater level data in the area and is likely representative of the Refuge's groundwater resources (USGS 371211089160501), especially in the southern portion where the Mississippi River Valley alluvial aquifer system is present, which is the same aquifer associated with this monitoring site. This well recorded data from Jan 8, 2004 – Nov 4, 2013.

Water levels here have in the past oscillated between 13-15 ft. below ground level (Figure 29Figure 29 Depth to groundwater at well near Sandy Creek in Alexander County- USGS 371211089160501), though sampling prior to 2010 was infrequent and may not provide an accurate representation of past groundwater levels. Groundwater at this site appears to have a close relationship with surface water, since groundwater levels emulate trends of the Mississippi River. For example, during the 2011 flood event, the water table at this site reached its highest on May 10 at 4.58 feet below the land surface, shortly after the Mississippi River reached its maximum gage height of 44.35 ft on May 2, 2011. This information implies a surface and ground water interaction facilitated by very porous soils with groundwater levels that quickly respond to river levels.

Carbonate bedrock in this area is quite permeable, allowing relatively rapid recharge of the Ozark bedrock underlying Sandy Creek. Sinkholes and other karst features may exist here and accelerate aquifer recharge rates. While this relatively quick aquifer response secures a higher volume of groundwater resources for use in the long-term, rapid penetration through subsurface macropores deprives water of the filtering function that comes with longer travel times through the soil. This may cause groundwater resources in this area to be especially prone to contamination.

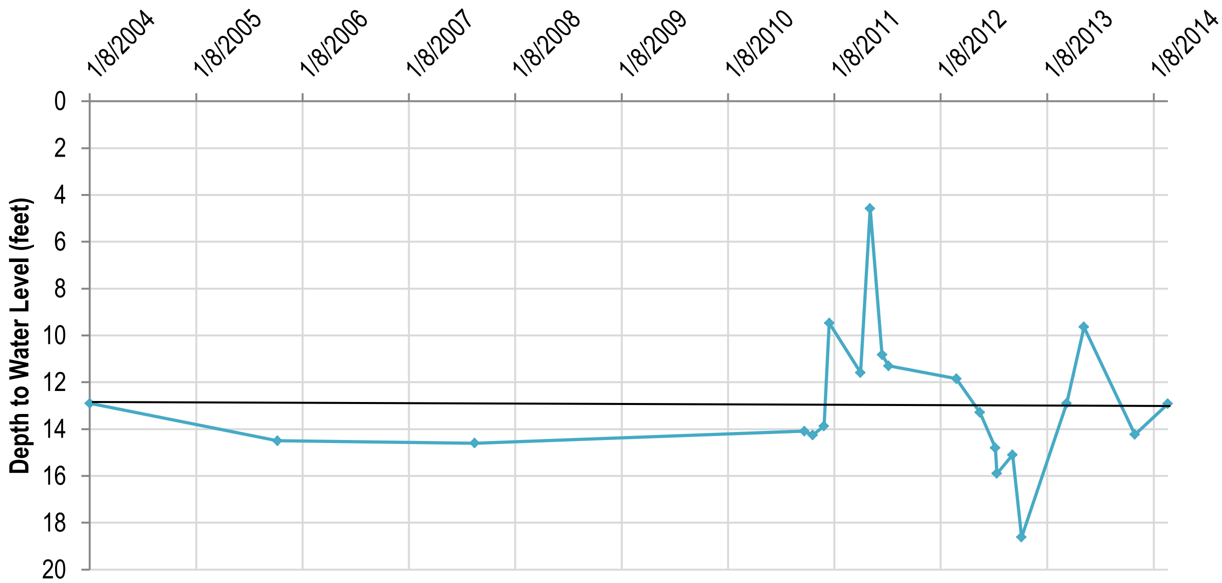


Figure 29 Depth to groundwater at well near Sandy Creek in Alexander County- USGS 371211089160501

1.11 Surface Water Quality

Many of the relevant monitoring sites identified through the EPA STORET database housed no data, limited datasets, or were not in a location considered relevant by US FWS hydrologists. In addition to water chemistry data obtained from EPA and USGS databases, water quality information found in several reports and peer-reviewed journal articles may be applicable to Refuge water resource management. Some of this information, along with a summary of the CAP status and 303(d) reporting information, are summarized in the subsections below

1.11.1 Big Creek

This creek is the most significant tributary source of sediment loading to the Lower Cache River and the internationally-recognized Cache River Wetlands, accounting for over 70 percent of the sediment loading to the Lower Cache in the late 80s (Demissie et al., 2001). Most of the sediment transport occurs during infrequent, annual floods, and the maximum annual load ranged from 7,229 tons-50,840 tons in the ‘80s (Demissie et al., 1990a). The Big Creek channel is relatively steep (0.338%), which is part of the reason it is prone to erosion and sedimentation (Guetersloh, 2002), and excessive downstream widening (Dodd et al., 2001).

Because of these issues, management of Big Creek is especially important for sedimentation mitigation plans for the Cache River and its wetlands. The hydrology of this tributary is particularly important because it is a major contributor to the reverse-flow conditions at its confluence with the Lower Cache River. Various management options for Big Creek with respect to restoring westerly flow conditions toward the Mississippi River are discussed by Demissie et al. (2001).

Despite sediment and other water quality threats to the drainage, such as high dissolved reactive phosphate concentrations (Blattel et al. 2005), the biotic community of Big Creek is relatively healthy. Fish sampling in the 90s have shown IBI score ranging from 34-44 (good), and a macroinvertebrate community index of 4.9 (good) at Big Creek (Demissie et al., 2010).

1.11.2 Upper and Lower Cache Rivers

Both the Upper and Lower Cache Rivers have suffered water quality impairments as a result of the 1915 diversion, such as increased slope, channel incision, severe erosion, disconnection from floodplain, wetland loss, and incision and widening due to headcutting in the Upper Cache. Its base level has since dropped by 12.2 meters, and the drainage network down-cut to the bedrock, an effect that is migrating upstream and continues to erode the streambanks (Heine, 2004).The most detrimental Lower River impacts have been in the form of decreased flows, high discharge floods, habitat degradation post-diversion, as well as low dissolved oxygen levels and sedimentation, issues which are most apparent in the low flows of the summer .

Low dissolved oxygen (DO) concentrations have resulted in recent fish kills in the Lower Cache River (Bouska et al. 2012). DO levels typically fluctuate around 1 mg/L throughout most of the year but occasionally reach 20 mg/L in the summertime (Rantala et al., 2010). Persistently low DO in the Lower Cache may impair ecosystem functions and have implications for species diversity and abundance. Comparatively higher DO concentrations (5-9 mg/L) have been measured in the Upper Cache Basin, with little fluctuation between daytime and nighttime values.

Sediment storage is a natural function of the Lower Channel because of its low-gradient, however higher erosion rates and increased sedimentation in the Watershed have caused these processes to become one of the most serious threats to the habitat and ecosystem. Bathymetric sedimentation surveys of the Lower Cache River Wetland area in 2000 revealed depositional rates of approximately 0.2-2cm/year (Allgire and Cahill, 2001), and the issue could increase in rate if hydrologic restoration measures are not implemented, considering wetter conditions are expected in the region in the future.

The Lower Cache exhibits the highest dissolved reactive phosphorus levels compared to concentrations associated with Big and Cypress Creeks, and the Basin’s concentrations are higher than others measured throughout the entire State (Blattel, et al., 2005). This is probably due to higher water tables in this area, which leads to lower oxygen concentrations and the release of ferrous iron. These higher levels are likely caused by the release of phosphate bound to clay colloids rather than fertilizer application and land use practices around this site (Blattel et al., 2005).

Some water quality differences between the two Rivers have been noted by Scholl (2009). Macroinvertebrates in the Lower Cache River are generally more adapted to low flows and degraded habitat, and are lower in body size than communities sampled in the Upper Cache where the River’s flow regime more closely resembles its natural state. This information suggests poor water quality in the Lower Basin. Similarly, IDNR fisheries surveys have shown moderately low average biotic integrity indices in the upper Cache River basin and lower biotic integrity indices in the lower Cache mainstem from 1992-2011 (Muir, 2011), and higher biotic integrities have generally been observed in upstream reaches compared to downstream reaches (Bennett et al. 2001). There is also some evidence that weirs in the Upper Basin support higher invertebrate diversity than non-weir sites in the Lower Basin due to higher cobble habitat, and these differences have influenced bird diversity and other ecosystem functions (Walther and Whiles 2008; Heinrich 2011; Bouska et al. 2012).

1.11.3 Contaminants Assessment Process (CAP)

Brian Wiebler (USFWS) completed the contaminants assessment process (CAP) in 2001 for CCNWR. This included the identification of contaminant sources and pathways into CCNWR, as well as recommendations for future water and sediment sampling sites. The major hydrologically relevant conclusions within the CAP were (Wiebler, 2001):

- Sedimentation of the Cache River, caused by poor farming practices in the surrounding area and headcutting as streams straightened, led to reduced wetland productivity and a mechanism to transport contaminants.
- Pulaski Slough and the lower Cache River were identified by the Illinois EPA to have elevated contaminants in 1992, though the source of these contaminants was unknown.
- Mercury, arsenic, and chlordane were found in high levels in 1992 in areas surrounding, but not necessarily providing significant drainage into CCNWR.

Another CAP, led by Mike Brown, Karen Mangan, Josh Eash, Brian Newman, and Mike Coffey (USFWS), has been underway since 2011, and a draft summary was completed in October 2013. Some of the tentative hydrologically-significant points include:

- Aquatic life use impairments of the Cache River have been caused by total phosphorus and sedimentation issues.
- Water from the Mississippi and Ohio Rivers may back up into the Refuge and influence water quality. Nutrients and agricultural chemicals are the biggest concerns associated with this pathway.
- At the same time, the Mississippi River, Ohio River, and ultimately the Gulf of Mexico, are also at risk of contamination from pollutants released within CCNWR.
- The Cache River seems to be the surface water pathway with the highest number of contaminant sites associated with it, followed by Sandy Creek. Since future restoration activities in and near the Refuge might reconnect flow from the Upper Cache River, such activities should be done with careful consideration to the potential contaminant-related costs that may come with increased flow from this River.
- Though groundwater quality within the Cache River watershed are not listed as impaired, shallow alluvial groundwater seeps that discharge into the Cache River may be inputting excessive nutrients into the Refuge, since there is row crop land use and high fertilizer application rates in the uplands and floodplains.
- Agricultural sources are the biggest concern in terms of surface water contamination, and chemicals, pesticides, and municipal wastewater contaminants (e.g. salts, hydrocarbons, and metals) are the primary pollutants threatening the Refuge.
- Several flowpaths were identified as potentially contaminated areas, where possible contamination pathways intersect CCNWR's boundaries, and may be important target areas for future sampling efforts. Most of these sites are likely contaminated with pesticides and nutrients from non-point sources, though some are contaminated because of sewage treatment effluent.

303(b) Reporting and 303(d) assessments

Section 303(d) of the Clean Water Act requires that each state identify water bodies where water quality standards are not met based on designated usage. Several water bodies listed in IEPA's 303(d) list of impaired waters are located within the Refuge's potential zone of hydrologic influence. Of these, the longest is a reach of Sandy Creek (ID IL_IXD-01), where 13.42 miles are affected by dissolved oxygen, preventing the stream from meeting its designated use for aquatic life. Channelization, loss of riparian habitat, crop production, and agriculture are listed as sources for these water quality problems. Portions of the Cache River (IDs IL_IX-03 and IL_IX-05, 11.74 miles total) are also limited for aquatic use by poor dissolved oxygen levels and high sedimentation/siltation, likely due to upstream channelization and crop production (IEPA, 2012). Details about IEPA's 2012 assessment information for specific reaches are summarized below (Table 6, Figure 30). A lack of "impaired" designation for a waterway within CCNWR's RHI does not preclude issues of concern, since small ditches and wetlands do not have well-defined standards and are not typically assessed by state organizations.

IEPA's 303(d) List (2012)

Priority	Water ID	Waterbody Name	Miles/Acres	Designated Use	Impairment
46	IL_IX-03	Cache R.	3.97	Aquatic Life	Sedimentation/Siltation
58	IL_IX-05	Cache R.	7.77	Aquatic Life	DO, Sedimentation/Siltation
46	IL_IXI-01	Indian Camp Cr.	1.35	Aquatic Life	Sulfates
46	IL_IXDB	West Br. Sandy Cr.	4.64	Aquatic Life	Cadmium, DO, pH
9	IL_IXC	Boar Cr.	7.69	Aesthetic Quality	Bottom Deposits, Turbidity
9	IL_IXC	Boar Cr.	7.69	Aquatic Life	DO
46	IL_IXD-01	Sandy Cr.	13.42	Aquatic Life	DO, pH
46	IL_IXFA	Jackson Cr.	6.6	Aquatic Life	DO
46	IL_IXDA	Wolf Cr.	4.67	Aquatic Life	DO

Table 6 Impaired waterbodies relevant to CCNWR (IEPA, 2012)

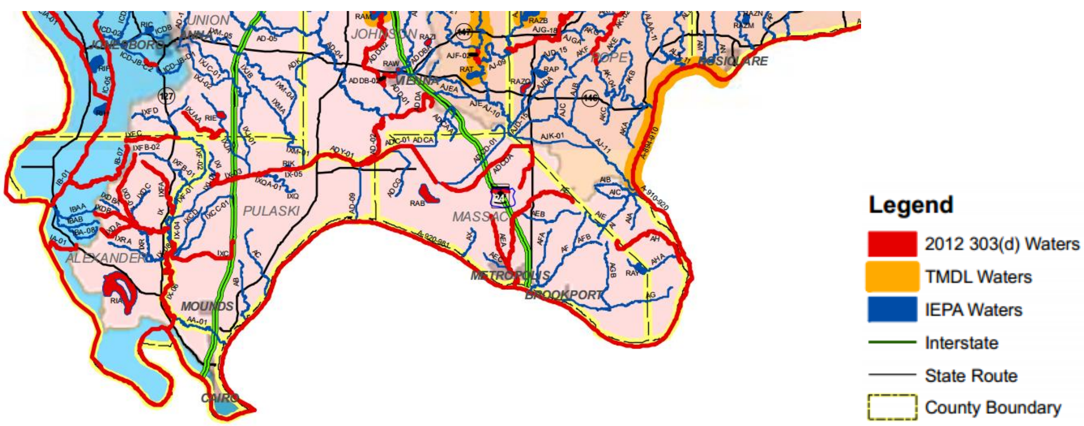


Figure 30 303(d) listed waters in southern Illinois (IEPA 2012, http://www.epa.state.il.us/water/tmdl/303-appendix/2012/appendix-a5.pdf)

The following reaches were in full attainment for the designated uses for which they were assessed (IEPA, 2012):

- Cypress Creek (IL_IXM-01, 7.13 miles; IL_IXM-04, 5.35 miles; IL_IXM-05, 13.65 miles): aquatic life
- Little Creek North (IL_IXM-05, 13.65 miles): aquatic life
- Big Creek (IL_IXJ-02, 10.02 miles): aquatic life
- Cache River (IL_IX-04, 7.32 miles): aquatic life and aesthetic quality
- Hartline Creek (IL_IXFC, 5.37 miles): aquatic life and aesthetic quality
- Lingle Creek (IL_IXFD, 4.74 miles): aquatic life and aesthetic quality
- Mill Creek (IL_IXF-01, 7.14 miles; IL_IXF-02, 10.92 miles): aquatic life

In 2014, the reach of the Lower Ohio River Watershed, bordering southern Illinois, was listed as impaired for mercury, PCBs, dioxin, and fecal coliform. The bordering Mississippi River reach was listed for mercury, PCBs, and fecal coliform (IEPA 2014).

There has been a fish advisory within the Refuge RHI for Indian Camp Creek and Horseshoe Lake due to PCB levels (IDPH 2014). In addition, 10.4 miles of the Cache River that flow through CCNWR (IX08) have also had a fish advisory for mercury impairments. The Ohio River has had several advisories as well for both PCBs and mercury, and advisories have been made for the Mississippi River for PCBs. Though these are downstream of the Refuge RHI, they are still relevant because of the potential for contaminated fish migration into Refuge waterbodies. While there is not a current fish advisory for the Cache River, several of its reaches have been listed as impaired for fish consumption use due to mercury concentrations (IEPA, 2012).

Water Law

IDNR is the state agency with the most direct regulatory authority over wetlands in Illinois. The primary authority of this agency is established in the Interagency Wetlands Policy Act of 1989. This Act provides the Department with regulatory authority over state activities that affect wetlands. The Interagency Wetlands Policy Act established the goal of “no overall net loss of the state’s existing wetland acres or their functional values due to state supported activities.” Illinois is the second state to adopt a “no net loss goal” in legislation with the passage of this Act. Additional regulatory authority is in the Rivers, Lakes, and Streams Act, which provides the Department with regulatory authority over activities in floodplains. The regulatory program requires permits for construction in the floodway of any stream serving a tributary area of 640 acres in urban areas, or 6,400 acres in rural areas. Information on permitting requirements is available from the IDNR (http://www.dnr.illinois.gov/WaterResources/Pages/default.aspx). Permits may be necessary for construction activities that discharge into wetlands and for dredge and fill activities in floodplains of waterways which contain catchments of greater than 6,400 acres. However, routine maintenance typical of agricultural activities is excluded from these requirements (i.e. ditch maintenance, tile installation, etc.).

The Illinois EPA is the agency responsible for reporting to the USEPA on the status of surface water and groundwater under sections 305(b) and 303(d) of the Federal Clean Water Act (CWA). Additionally, the IL EPA is the permitting and enforcement authority for groundwater, drinking water, storm water runoff and pollution discharge permits. The Illinois EPA established the Groundwater Quality Standards (GWQS) (35.Ill.Adm.Code 620), detailed explanations and listings for which can be found through the Illinois Pollution Control Board’s webpage (http://www.ipcb.state.il.us/).

From the DOI Solicitor office:

In states that apply the riparian rights doctrine, landowners of property with naturally flowing surface water running through or adjacent to their property have rights to reasonable use of the surface water associated with the property itself. The “reasonable use” standard protects downstream users by ensuring that one landowner’s use does not unreasonably impair the equal riparian rights of others along the same watercourse. Additionally, the law limits riparian rights to those rights “intimately associated” with the water; uses falling outside of this definition are usually considered unreasonable uses.[1]

An important corollary to the riparian rights doctrine is that, generally, states classify their navigable[2] *surface waters as public, whether through statute or through the common law public trust doctrine.*[3] *This is important because on public waters, the riparian landowners’ rights are*

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[1] John W. Johnson, United States Water Law: An Introduction 38 (CRC Press, 2009).
[2] “Navigable,” in this context, is a legal term of art that varies from state to state, separating public waters from those that are private. As a general notion, “navigable” means navigable in fact, which, historically, has been tested by whether or not a log or canoe could float on the water. *See, e.g.*, Paul G. Kent & Tamara A. Dudiak, *Wisconsin Water Law: A Guide to Water Rights and Regulations* 4 (University of Wisconsin-Extension, 2d ed., 2001).
[3] The public trust doctrine, in most states, refers to the concept that state, as trustee to the public, preserves navigable waters “for public use in navigation, fishing and recreation.” Black’s

subject to public rights of, at a minimum, navigation. For this reason, states regulate waters for the purpose of putting the water to "beneficial use," a term defined differently amongst the states.

Illinois does not have a sophisticated means for claiming rights to water, especially for instream water rights. As a state that generally follows the traditional riparian rights doctrine,[4] all landowners adjacent to a body of water have a right to reasonable use of the water, so long as it does not impact the same rights as other similarly situated landowners.[5] The legislature codified surface and ground water into one system under the Water Use Act of 1983, which extended the common law reasonable-use rule to groundwater withdrawals.[6]

The statute specifically defined "reasonable use," in keeping with the common law, as "the use of water to meet natural wants and a fair share for artificial wants. It does not include water used wastefully or maliciously."[7] In Illinois, "natural wants" refer to uses necessary to the land, mainly domestic uses.[8] "Artificial wants," on the other hand, refer to uses that would increase "comfort and prosperity."[9] In times of shortage, the state will prioritize natural wants over artificial wants, and once natural wants are satisfied, water users may consume their "just proportion" of artificial wants.[10] Courts ultimately determine on a case-by-case basis whether a water user has consumed beyond his "just proportion," looking at the relative needs of the water users and the water availability.[11]

With the reasonable-use rule as a foundation, Illinois allows communities to regulate groundwater consumption through the establishment of water authorities, in order to give communities the power to take control of their local resource. The Water Authority Act (WAA) sets out a detailed and extensive procedure for citizens to create a water authority, but once established, the local authority has broad powers.[12]

At least thirteen water authorities have been established since the law was enacted, mostly in the eastern-central part of the state.[13] However, the WAA specifically excludes water used for agricultural purposes, irrigation, and small domestic wells for less than four families from the Authorities jurisdiction.[14] The law does not provide any specific authority for water authorities to ensure minimum flows or instream uses, but at least provides a broad catchall, allowing

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Law Dictionary 1232 (6th ed. 1990). This prohibits the state from selling the beds to private parties.

[4] *Evans* v. *Merriweather*, 4 Ill. 491 (1842); *Knaus v. Dennler*, 525 N.E.2d 207, 209 (Ill. App. Ct. 1988).

[5] Gary R. Clark, *Illinois Groundwater Law: The Rule of Reasonable Use* 14–15 (State of Illinois, Department of Transportation and Division of Water Resources 1985).

[6] Water Use Act of 1983, 525 Ill. Comp. Stat. 45/6 (2011).

[7] 525 Ill. Comp. Stat. 45/4.

[8] *Evans* v. *Merriweather*, 4 Ill. 491, 495 (1842).

[9] Id.

[10] *Bliss v. Kennedy*, 43 Ill. 67, 74 (1867).

[11] *Id.* at 76–77.

[12] 70 Ill. Comp. Stat. 3715/1 *et seq.* (2011).

[13] *See* http://www.isws.illinois.edu/docs/wsfaq/wsmore.asp?id=q6; http://www.agr.state.il.us/marketing/IALD/organizations/IALDDirectory%2058.pdf.

[14] 70 Ill. Comp. Stat. 3715/8 (2011).

authorities to "make such regulations as it deems necessary to protect public health, welfare and safety and to prevent pollution of its water supply."[15] This may be the only provision FWS could rely upon to protect instream flows within a local water authority region.

In addition to the local water authorities, the Illinois Department of Natural Resources (DNR) has jurisdiction over public waters, and the agency has a duty to document all navigable waters and "jealously guard the true and natural conditions" of state waters.[16] Under this policy, DNR's Office of Water Resources manages a permit system for construction projects in public water ways, i.e. navigable waters, and for public water developments that may impact public rights to use the water.[17]

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In Illinois, FWS has a right to the reasonable use of surface and ground water associated with the boundaries of the Refuges. While FWS cannot affirmatively assert its right to instream use, it may have a claim against other water users if a shortage occurs, even if that right consists of a just proportion of its natural wants.[20] However, these issues have yet to be explored by the courts.

[15] 70 Ill. Comp. Stat. 3715/24 (2011).
[16] 615 Ill. Comp. Stat. 5/5 (2011).
[17] Ill. Admin. Code tit. 17 §§ 3700, 3704, 3708 (2010).
[18] 615 Ill. Comp. Stat. 5/5 (2011).
[19] Ill. Admin. Code tit. 17 §§ 3700, 3704, 3708 (2010).
[20] Illinois courts have not spoken on whether instream uses for fish and wildlife purposes would constitute a natural want.

Geospatial Data Sources

HUC polygons are available from the EPA as part of the Watershed Boundary Dataset (WBD). These boundaries were delineated in cooperation with the USGS using methodology adapted from Seaber et al (1987)

High resolution LiDAR data (1 m cell size) was processed and merged for the Refuge by Vince Capeder (USFWS, 2014)

Multiple types of geospatial layers are available from the USGS National Atlas website (http://nationalatlas.gov/maplayers.html), the USGS Mineral Resources Program website (http://mrdata.usgs.gov/geology/state/state.php?state=IL), and the Illinois State Geological Survey website (http://crystal.isgs.uiuc.edu/nsdihome/).

The National Wetland Inventory- U. S. Fish and Wildlife Service. 1985-1986. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/

Background aerials are from the U.S. Department of Agriculture National Agriculture Imagery Program.

The National Hydrologic Dataset (NHD) is produced as a cooperative effort by the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and other federal and state agencies.

United States Geological Survey (2014). Principal aquifers of the 48 conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands. <http://maps.google.com/gallery/details?id=z4f-ZuCLmiKg.ku3UD0DP0zkk&hl=en>.

Literature Cited

Allgire, R.L. and Cahill, R.A. (2001). Benchmark sedimentation survey of the Lower Cache River Wetlands. Prepared for Illinois Department of Natural Resources.

Angel, J. (2010). State Climatologist Office for Illinois: Climate events of 2009 in Illinois. http://www.isws.illinois.edu/atmos/statecli/events2009.htm

Bennett, D. A., Vitale, A. J. (2001). Evaluating nonpoint pollution policy using a tightly coupled spatial decision support system. *Environment Management, 27*(6), 825-836. doi:10.1007/s002670010191 [Cypress Creek]

Blattel C.R., Williard, K.W.J., Baer, S.G., Zaczek, J.J. (2005) Abatement of ground water phosphate in giant cane and forest riparian buffers. Journal of the American Water Resources Association 41(2): 301-307.

Blattel, C.R., Karl W. J. Williard, K.W.J., Baer, S.G., Schoonover, J.E., and Zaczek, J.J. (2009). Ground Water Nitrogen Dynamics in Giant Cane and Forest Riparian Buffers. Castanea: October 2009, Vol. 74, No. 3, pp. 259-270.

Bouska, K. Erndt-Pitcher, K., Lloyd, A., Nelson, A. Stoebner, T. Challenges to integrating human and natural systems: an assessment of the Cache River Watershed. (2012). Southern Illinois University Carbondale. 182p.

Cache River Watershed Resource Planning Committee. (1995). Resource Plan for the Cache River Watershed: Resource Concern #6 Post Creek Cutoff. Available online: <http://friendsofcache.org/pdf_files/concern_6_post_creek_cutoff.pdf>

Changnon, S.A., Angel, J.R., Kunkel, K.E.., Lehmann, C.M. (2004). Illinois Climate Atlas. Illinois State Water Survey, Champaign Illinois.

Coffey, M. and Mangan, K.E. (2011). Cypress Creek National Wildlife Refuge Contaminants Assessment Process. Accessbile online: <https://ecos.fws.gov/cap>.

Corzine, A.E. (2010). Report on the present conditions of a Southern Illinois Natural Landmark. The Citizens Committee to Save the Cache River.

Cowardin, L.M, V. Carter, F.C. Golet, & E.T. LaRoe. (1979). Classification of wetlands and deepwater habitats of the United States. Department of the Interior. U.S. Fish and Wildlife Service, Washington*, D.C.* 131 p.

Demissie, M., T.W. Soong, R. Allgire, L. Keefer, and P. Makowski, (1990). Cache River Basin: Hydrology, Hydraulics, and Sediment Transport, Volume 1: Background, Data Collection, and Analysis. Illinois State Water Survey Division Contract Report 484. Illinois Department of Conservation. Champaign, IL.

Demissie, M., Fitzpatrick, W. P., & Cahill, R. A. (1992). Sedimentation in the Cache River wetlands: Comparison of two methods. SWS Miscellaneous Publication; 129. Champaign, IL: Illinois State Water Survey, Illinois State Geological Survey, Department of Energy and Natural Resources. Retrieved from http://www.isws.illinois.edu/pubdoc/MP/ISWSMP-129.pdf

Demissie, M., Knapp, H. V., Parmar, P, & Kriesant, D. J. (2001). Hydrology of the Big Creek Watershed and its influence on the Lower Cache River. Champaign, IL: Illinois State Water Survey. ISWS CR 2001-06 Retrieved from http://www.isws.illinois.edu/pubdoc/CR/ISWSCR2001-06.pdf

Demissie, M., Keefer, L., Lian, Y., & Yue, F. (2007). The importance of managing sedimentation in the Cache River wetlands. In Kabbes, K. C. (Ed.) Restoring our natural habitat: proceedings of the 2007 World Environmental and Water Resources Congress : May 15-19, 2007, Tampa, Florida. Reston, VA: American Society of Civil Engineers. (10 pages) doi:10.1061/40927(243)626

Demissie, M., Keefer, L., Lian, Y., Yue, F., & Larson, B. D. (2008). Hydrologic and hydraulic modeling and analyses for the Cache River for the purposes of evaluating current conditions and alternative restoration measures. Champaign, IL: Center for Watershed Science, Illinois State Water Survey. ISWS CR 2008-01 Retrieved from http://hdl.handle.net/2142/8873

Demissie, M., Lian, Y., Bekele, E., and Keefer, L. (2010). Hydrologic and hydraulic modeling for evaluation alternatives for managed connection of the Upper and Lower Cache Rivers. ISWS Contract Report 2010-06. Champaign, Illinois.

Dodd, H.R., Wahl, D.H., McIsaac, G.F., Hoxmeier, J.H., and Roseboom, D. (2001). Evaluation of watershed management practices for improving stream quality in the Illinois Watershed Program. Project F-136-R. 28 p.

Duram, L.A., Bathgate, J., and Ray, C. (2004). A local example of land-use change: Southern Illinois - 1807, 1938, and 1993. Professional Geographer, 56, 127-140.

Federal Emergency Management Agency. (2012). Discovery Report: Cache River Watershed, 07140108. Alexander, Johnson, Pulaski, and Union Counties, Illinois. 16 pp. Available online: <http://www.illinoisfloodmaps.org/DFIRMpdf/discovery/cache/CacheDiscoveryReport.pdf>

Heitmeyer, M.E. and Mangan, K.E. (2012). Hydrogeomorphic evaluation of ecosystem restoration options for Cypress Creek National Wildlife Refuge, Illinois. Prepared for: US FWS Division of Refuges, Region 3. Greenbrier Wetland Services Report 12-05. 63p.

Hutchinson, M.D. (1984). Lower Cache preservation plan. Prepared for The Nature Conservancy, Rockford, IL.

Gough, S.C. (2005). Historic and prehistoric hydrology of the Cache River, Illinois. Unpublished report to the Cache River Joint Venture Partnership (JVP). Little River Research & Design, Murphysboro, Illinois.

Groisman, P.Ya., R.W. Knight, D.R. Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev, (2005). Trends in intense precipitation in the climate record. Journal of Climate, 18(9), 1326-1350

Guetersloh, M. (2002). Big Creek Watershed Restoration Plan: A component of the Cache River Watershed Resource Plan. Prepared for the Cache River Watershed Resource Planning Committee. 52 p.

Hayhoe, K., J. Vandorn, V. Naik and D. Wuebbles. (2010). Climate change in the Midwest prokections of future temperature and precipitation trends. 28 pp.

Heinrich, K. (2011). Insect emergence and riparian bird responses to rock weir construction in the Cache River Basin of Southern Illinois. Southern Illinois University Carbondale.

Heitmeyer, M.E. and K.E. Mangan, (2012). Hydrogeomorphic Evaluation of Ecosystem Restoration Options for Cypress Creek National Wildlife Refuge, Illinois. Prepared for U.S. Fish and Wildlife Service, Region 3, Minneapolis, MN and Cypress Creek National Wildlife Refuge, Ullin, IL. Greenbrier Wetland Services Report 12-05, Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

Holmes, R.R. (1996). Hydraulic, geotechnical, geomorphic, and biologic data for the Cache River/Heron Pond area in southern Illinois. USGS Open File Report 96-467.

Hutchinson, M.D. (1984). Lower Cache preservation plan. A report prepared for The Nature Conservancy, Rockford, IL.

Hutchinson, M.D. (2000). Hydrologic history of the Lower Cache River Natural Area in Southern Ilinois. The Nature Conservancy. Ullin, Illinois.

Illinois DNR. (1997). Cache River Area Assessment, Volume 1 Part 1: Hydrology, Air Quality, and Climate. Office of Scientific Research and Analysis. Champaign, Ill. Available online: https://www.ideals.illinois.edu/handle/2142/13872

Illinois Department of Natural Resources. (2000). The Cache River Basin: An inventory of the Region's resources. http://hdl.handle.net/2142/13965

Illinois Department of Natural Resources. (2014). Cache River State Natural Area. < http://dnr.state.il.us/lands/Landmgt/parks/r5/CACHERVR.HTM>.

Illinois Department of Public Health. (2014). Fish advisories for Illinois. < http://www.idph.state.il.us/envhealth/factsheets/fishadv.htm>.

Illinois Environmental Protection Agency. (2002). Effective Discharges of Illinois Streams. D.W. Crowder and H.V. Knapp. Contract Report 2002-10. Available at <http://webh2o.sws.uiuc.edu/pubdoc/CR/ISWSCR2002-10.pdf>

Illinois Environmental Protection Agency. (2009). NPDES Facilities in Illinois. <http://www.epa.state.il.us/water/permits/waste-water/npdes-statewide.pdf>

Illinois Environmental Protection Agency. (2012). Illinois Integrated water quality report and section 303(d) list, 2012. Water resource assessment information and list of impaired waters. 111p.

Illinois Environmental Protection Agency. (2013). Upper Big Muddy Watershed Total Maximum Daily Load Stage One Report (DRAFT). Prepared by: LimnoTech, Inc. Available at: <http://www.epa.state.il.us/water/tmdl/report/upper-big-muddy/stage-one-draft.pdf>.

Illinois Environmental Protection Agency. (2014). Illinois Integrated water quality report and section 303(d) list, 2014. Water resource assessment information and list of impaired waters.

Illinois State Geological Survey and Illinois Department of Natural Resources. (2007). Geology of Karnak Quadrangle. Prepared by W.John Nelson and Jena Hintz.

Illinois State Water Survey. (2009). State Climatologist Office for Illinois: Average Wind Speed in Illinois. http://www.isws.illinois.edu/atmos/statecli/wind/wind.htm

Mankowski, A. (1997). Living Resources. In: IL Deparment of Natural Resources (ed.) Cache River Area Assessment.

Menne, M.J., Williams Jr, C.N and R.S. Vose. NOAA National Climatic Data Center. Asheville, NC. Southern Climate Impacts Planning Program. (2014). Historical climate trends tool.

Middleton, B.A., and McKee, K.L. (2005). Primary production in an impounded baldcypress swamp at the northern limit of the range. Wetlands Ecology and Management, 13, 15-24.

Muir, D.B., R.L Hite, M.M. King, M.R. Matson. (1995). An Intensive Survey of the Cache River Basin, Summer 1992. State od Illinois environmental Protection Agency Bureau of Water Planning Section.

O'Brien, J.M. and Williard, K.W. (2006). Potential Denitrification Rates in an Agricultural Stream in Southern Illinois, Journal of Freshwater Ecology, 21:1, 157-162.

Phillips, D.L. 1994. A survey and restoration plan for natural freshwater springs in the vicinity of the Cache River and the Cypress Creek National Wildlife Refuge. Report prepared for the U.S. Fish and Wildlife Service, Cypress Creek National Wildlife Refuge.

Phillips, D.L. 1996. Plant species distribution of seep springs in the Cache River Region of Southern Illinois. M.S. Thesis, Southern Illinois University, Carbondale, IL.

Rantala, H., Scholl, E., Whiles, M., Wilkerson, G., and Bencini, C. (2010). Predicting ecological responses to reconnection of the Cache River. Cache River Symposium. Vienna, IL.

Sankarasubramanian, A., Vogel, R.M., and Limbrunner, J.F. (2001). Climate elasticity of streamflow in the United States. Water Resources Research, V. 37, No.6. p. 1771-1781.

Scholl, E.A. (2009). The influence of water velocity on aquatic macroinvertebrate functional structure and production in the Cache River in southern Illinois.

Seaber, P.R., Kapinos, F.P., and Knapp, G.L.. (1987). Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p.

Slack, J.R. and J.M. Landwehr, Hydro-Climatic Data Network (HCDN): A U.S. Geological Survey Streamflow Data Set for the United States for the Study of Climate Variations, 1874-1988, U.S. Geological Survey Open-File Report 92-129.

United States Army Corp of Engineers (USACE). (2004). Upper Mississippi River System Flow Frequency Study. <http://www.mvr.usace.army.mil/pdw/pdf/FlowFrequency/Documents/FinalReport/default.asp>

United States Environmental Protection Agency. (2000). Ambient Water Quality Criteria Recommendations: Information supporting the development of state and tribal nutrient criteria, rivers and streams in nutrient ecoregion IX. Washington, D.C.

United States Environmental Protection Agency, 2013, Level III and IV ecoregions of the continental United States: Corvallis, Oregon, U.S. EPA, National Health and Environmental Effects Research Laboratory, map scale 1:3,000,000, http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm.

United States Environmental Protection Agency. (2000). Ambient Water Quality Criteria Recommendations: Information supporting the development of state and tribal nutrient criteria, rivers and streams in nutrient ecoregion IX. Washington, D.C.

United States Fish and Wildlife Service. (1990). Cypress Creek National Wildlife Refuge Environmental Assessment. Appendix L-Letter from Regional Director to the Chairman of the Big Creek #2 Drainage District.

United States Fish and Wildlife Service. (2010a). Operational Blueprint for Inventory and Monitoring on National Wildlife Refuges: Adapting to Environmental Change. 45 pp.

United States Fish and Wildlife Service. (2010b). Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change. 56 pp.

United States Fish and Wildlife Service. (2011). Rising to the urgent challenge: strategic plan for responding to accelerating climate change. 36 pp.

United States Geological Survey. (2004). Estimating Flood-Peak Discharge Magnitudes and Frequencies for Rural Streams in Illinois. Scientific Investigations Report 2004-5103.

Walther, D.A., and Whiles, M.R. (2008). Macroinvertebrate responses to constructed riffles in the Cache River, Illinois, Environmental Management, 41, 516-527.

Wiebler, B. (2001). Cypress Creek National Wildlife Refuge Contaminants Assessment Process. Accessbile online: <https://ecos.fws.gov/cap>.

Winkler, J.A., Arritt, R.W., Pryor, S.C. (2012). Climate Projections for the Midwest: Availability, Interpretation and Synthesis. In: U.S. National Climate Assessment Midwest Technical Input Report. Available from the Great Lakes Integrated Sciences and Assessment Center < http://glisa.umich.edu/media/files/NCA/MTIT_Future.pdf>.

Appendix A: Restoration Efforts in the Cache River Watershed

Management activities at CCNWR are just one component of broader cooperative efforts to protect and sustain the Cache River Watershed's resources (Figure 31), and organized goals to restore the Cache Basin's natural features have been underway for roughly 40 years. Shortly following CCNWR's establishment, TNC established the Grassy Slough Preserve as a Bioreserve Project, and in 1991 Ducks Unlimited helped with the creation of the Frank Bellrose Waterfowl Reserve within CCNWR. IDNR manages the 14,489-acre Cache River State Natural Area northeast of the Refuge, as well as three nature preserves in the region—Section 8 Woods, Heron Pond-Wildcat Bluff, and Little Black Slough. Over 10,300 acres have additionally been registered in IDNR's voluntary Land and Water Reserve Program, which supports the protection and management for lands and waters sustaining significant natural heritage or archaeological resources (IDNR 2014). The U.S. National Park Service has additionally recognized several features within or around CCNWR's boundaries as National Natural Landmarks—the Lower Cache River Swamp, Heron Pond-Little Black Slough Natural Area, and Horseshoe Lake Nature Preserve.

In 1991, a cooperative effort to restore the Cache River Watershed evolved between the USFWS, IDNR, TNC, NRCS, Ducks Unlimited, the Citizens Committee to Save the Cache River, and Friends of the Cache River. The Cache Wetland Joint Venture Partnership (JVC) manages roughly 60,000 acres of wetland area in the Lower Cache River. In addition, the USEPA, TNC, and the USDA NRCS helped fund the development of the Cache River Watershed Planning Committee, which is a small group of local residents who develop long-term plans for the Watershed's resources.

Several restoration initiatives have been focused in the Buttonland Swamp area. Some claim that the diversions from the Upper Watershed left the Swamp in a drier state since its water inputs became limited to Big and Cypress Creeks. In response, the Diehl Dam was constructed in an attempt raise the water levels of the Swamp, and now the floodplain experiences prolonged inundation through the entire growing season. There is some concern that this effect adversely impacts the wetlands' productivity, since Bald Cypress germination relies on cycles of flooding and drawdown (Middleton and McKee 2005).

Excessive sediment deposition in the Watershed alters natural flood patterns, and sedimentation has been listed as a cause of impairment for multiple water features in the watershed including the Cache River (IEPA 2012). From 1985-1988, a sediment quantification program was designed by the Illinois State Water Survey to identify a focus for restoration efforts. Specifically, sediment loads to the Cache River and Buttonland Swamp originating from Cypress Creek and Big Creek were quantified. The resulting publications and models estimate sediment transport in the Upper and Lower Cache Drainage Basins and provide likely outcomes of various management and restoration scenarios (Demissie et al. 1989, 1990, 1991, 2001, 2008, 2010).

As a follow-up, a sedimentation project was conducted by the Illinois State Water Survey (ISWS) and the Illinois State Geological Survey (ISGS) between 2000-2001 to provide comparative data on sediment response to land use changes and restoration efforts in the Buttonland Swamp area (Allgire and Cahill, 2001). The ISWS has since continued monitoring and modeling in the Big Creek and Cypress Creek drainage basins, and as a result of their findings IDNR (2000) Ecosystem Program funds have been focused on Big Creek restoration efforts and the construction of detention ponds to help improve flow conditions near the Buttonland Swamp area.

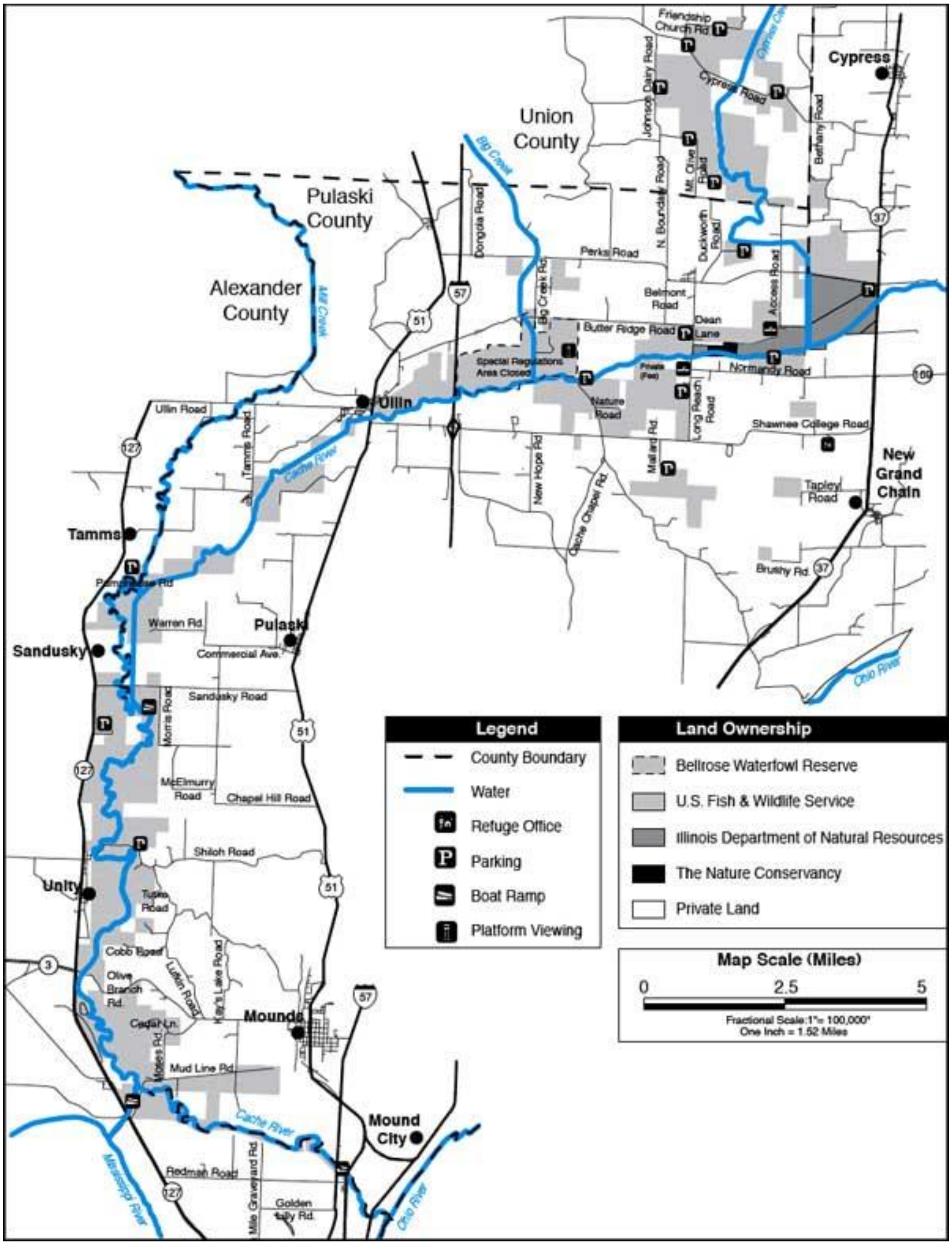

Figure 31 Land ownership in the Lower Cache Drainage Basin (http://www.thearmchairexplorer.com/illinois/i-images/nwrs/cypress-creek-mapbig01.jpg)

Appendix B: NWI Information

The NWI is based on interpretation of aerial photographs rather than ground surveys, and its criteria differ from those used in jurisdictional wetlands delineations for permitting by the USACE under Section 404 of the Clean Water Act.

This inventory includes a Cowardin classification (1979) codes for each wetland unit. The highest level of this hierarchical classification is the system, with five divisions: marine, estuarine, riverine, lacustrine, and palustrine. The second level is subsystems, which characterize structure and inundation regime. The third level is classes, which characterize substrate material and vegetation type. Classes are further divided into finer categories of substrate or vegetation type in the fourth level of classification. A habitat may also be categorized by any of 47 modifiers, including various water regimes, water chemistry parameters, soil parameters, and human modifications.

As with most remotely-sensed data, maps and statistics derived from the NWI have inherent errors and limitations, particularly for wetland type classifications and acreage. The accuracy of baseline inventories and classifications for data related to wetlands is limited by the quality of imagery, may be subject to errors of the imagery analysts' interpretations, and may not have been verified with ground truth surveys. Wetlands are also dynamic in nature, while the imagery used for the inventory represents a snapshot in time. Landscape and climate changes may have altered the composition and/or extent of the wetlands since the dataset was created.

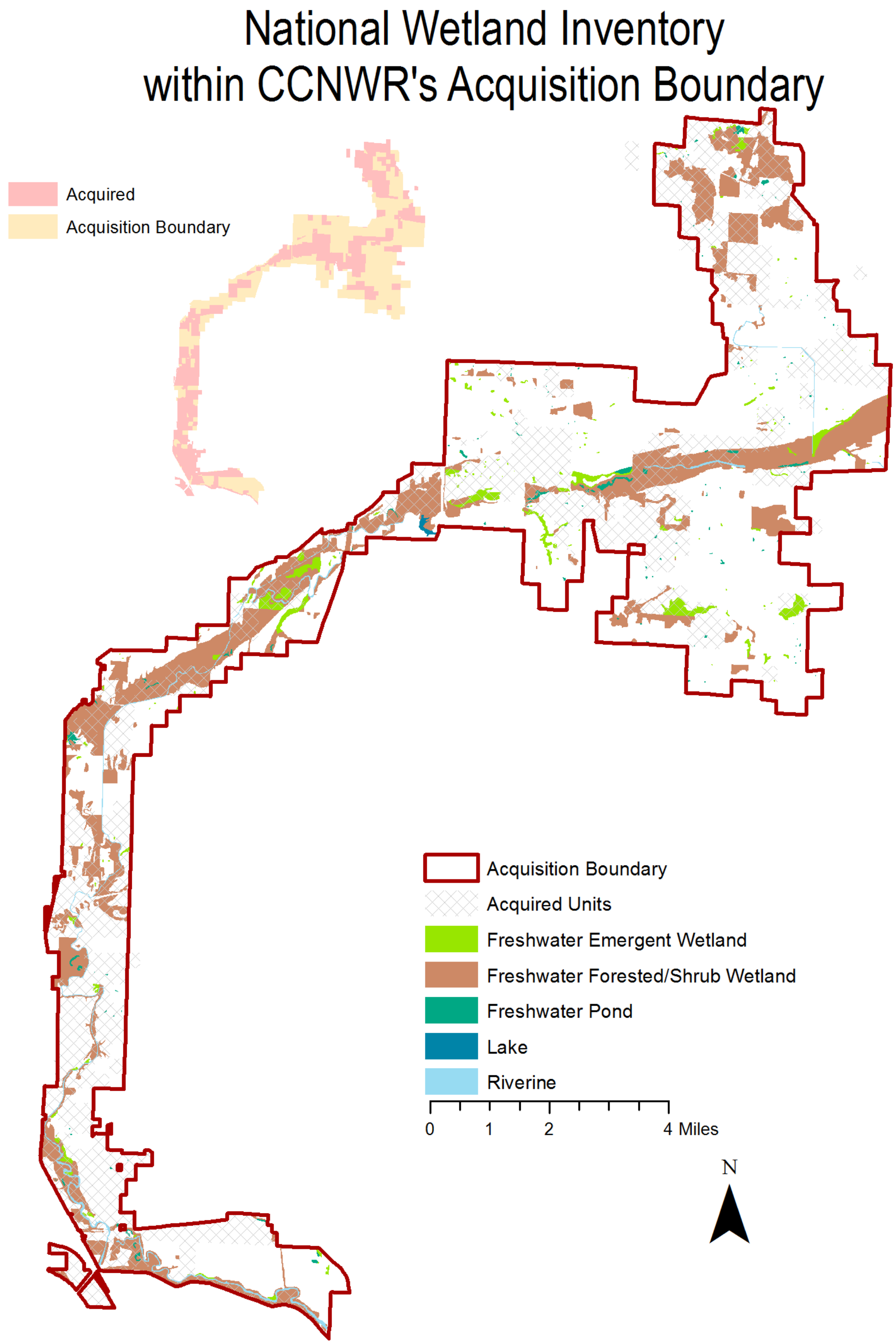

Figure 32 NWI wetland types within CCNWR's acquisition boundary

Wetland Type	Sum Acres (Acq Bndy)	Pct (Acq Bndy)	Sum Acres (Fee Bndy)	Pct (Fee Bndy)
Freshwater Emergent Wetland	781.40	9.27%	445.53	9.38%
Freshwater Forested/Shrub Wetland	7,045.19	83.56%	4,014.60	84.51%
Freshwater Pond	189.78	2.25%	93.34	1.96%
Lake	22.30	0.26%	0.00	0.00%
Riverine	392.66	4.66%	197.24	4.15%
TOTAL	8,431.33		4,750.71	

Table 7 Wetland type statistics for CCNWR

Wetland Code	Total (Acq Boundary)	% (Acq Boundary)
PFO1C	3435.48	40.49
PFO1A	1565.21	18.45
PFO6F	1029.00	12.13
PEMC	315.29	3.72
PSS1A	240.19	2.83
R2UBH	194.94	2.30
PSS/FO1F	151.08	1.78
PSS1F	145.64	1.72
PSS1/UBF	106.14	1.25
PSS1C	98.62	1.16
PEMA	89.57	1.06
R2UBHx	86.49	1.02
PEMCd	84.23	0.99
PEM/SS1A	78.56	0.93
PFO1Ad	69.70	0.82
PFO6/SS1F	66.13	0.78
PUBF	65.98	0.78
PSS1/EMC	61.69	0.73
PFO6FH	51.81	0.61
PEMAd	50.60	0.60
PUBG	47.86	0.56
PSS1Cd	44.71	0.53
PEM/SS1AD	44.61	0.53
TOTAL	8123.53	95.77

Table 8 Wetland codes for the majority (>95%) of wetland area within CCNWR acquisition boundary

Appendix C: Water Resource Monitoring Information

Site Name	ID (Link)	Alternate ID (Link)	Responsible Organization (s)	Data Available	Comments	Within Refuge? (Y/N)	Start date	End date
Big Creek near Wetaug, IL	USGS 05600000	N/A	USGS Illinois Water Science Center	Daily discharge data, 1940-1971; Pk strmflw data, 1942-2011; 3 water chem samples, 1961-1981	Just upstream of Refuge boundary; "Maximum discharge exceeded 7,200 ft³/s Mar. 19, 2008, gage height 15.74 ft, from rating curve extended above 2,500 ft³/s on basis of slope-area measurement of flow in main channel and computed flow through breaks in levees; maximum gage height, 16.32 ft, Mar. 6, 1945; no flow at times in 1941, 1954, 1963-64, and 1966."	N	1940	2012
Cache River at Sandusky, IL	USGS 05600150	N/A	USGS Illinois Water Science Center	168 water chem/nutrient/metal /wq samples, 1978-1997	Just upstream of site IX-04	Y	1978	1997
Cache R Miss	IL_EPA-IX-04	IL_EPA_WQX-IX-04	Illinois EPA	70 metal/water chem/a few pesticide/herbicide/ pollutant samples, 2003-2011; 2-4 water chem/nutrient samples, 2005	Several high phosphorus, TSS, iron, aluminum, and Kjeldahl Nitrogen readings. Also possibly high in lead, arsenic, and chlorophyll-a, fecal coliform, Many other points with similar data. This one probably has the most sample counts within CC boundary	Y	2003	2005
Mississippi River at Thebes, IL	USGS 07022000	N/A	USGS Missouri Water Science Center	Daily discharge/sediment data, 1933-2013; Pk strmflw data, 1844-2012; 1114 water chem, metal, nutrient, biological, pesticides, radiochemical, sediment samples, 1973-2013	“Water-discharge records poor. Natural flow of stream affected by many reservoirs and navigation dams in the upper Mississippi River Basin and by many reservoirs and diversions for irrigation in the Missouri River Basin.”	N	1933	present

Cache River at Forman, IL	USGS 03612000	Station #378	Illinois State Water Survey, USGS Illinois Water Science Center	Daily discharge, gage height, WQ/chemistry data; Hydraulic, Geotechnical, Geomorphic, and Biologic Data for the Cache River/ Heron Pond Area in Southern Illinois IDNR uses this site	Benchmark sediment monitoring program - water and atmospheric resources monitoring program (WARM)	N	1922	present
Cache River at Ullin, IL	Station #513	N/A	Illinois State Water Survey	Instantaneous suspended sediment data	No lat/long points… Benchmark sediment monitoring program - water and atmospheric resources monitoring program (WARM)	N	1995	2009
Cache River	Station #500	IL_EPA_ WQX-IXJ-02	Illinois State Water Survey; IEPA	daily Stage, Discharge, Sediment data 2000-2003; 1-7 samples for water chem, metals, herbicides/pesticides, 2004	Part of PILOT watershed monitoring program and chl-a study.	N	2000	2004
Big Creek	Station #502	N/A	Illinois State Water Survey	daily Stage, discharge, sediment, nutrient data (2000-2003)	Part of PILOT watershed monitoring program. Right by USGS 05600000	N	2000	2003
Cypress Creek	Station #503	N/A	Illinois State Water Survey	daily stage, discharge (not yet available), sediment data (1999-2003)	Part of PILOT watershed monitoring program	Y	1999	2003
Ohio River at Dam 53 near Grand Chain, IL	USGS 03612500	IL_EPA_ WQX-A-06	USGS Kentucky Water Science Center	Extensive data on gage height, sediment, metals, nutrients, biology, pesticides, PCBs, radiochemicals, 1954-2013; 1 WQ sample, 2004	Flow regulated by many dams and reservoirs. Phosphorus levels exceeding 0.1 mg/L standard	N	1954	present

14S 1E-7.2h	USGS 371856089 081801	N/A	USGS Illinois Water Science Center	1 gw level sample, 1977; 6 water chem, nutrient, pesticide, herbicide samples, 1991-2000	Nitrogen exceeding EPA's recommended criteria for aquatic life. High diazinon, terbuthylazine, and alpha-HCH-d6 concentrations in 1992	Y	1977	2000
003-5-13-4085	USGS 371211089 160501	N/A	USGS Illinois Water Science Center	20 gw level samples, 2004-2011	Dramatic changes in groundwater level from 2010-present.	N	2004	2011